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Development of a national knee ligament registry

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This thesis is dedicated to my girlfriend and best friend Maren, and our three children Frida, Lukas and Aksel.

“Those of you who say it can’t be done should not interrupt those of us who are doing it.”

George Bernard Shaw

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Contents

Abbreviations and Glossary

ACL	Anterior Cruciate Ligament
ACLR	Anterior Cruciate Ligament Reconstruction
ACL-RSI	ACL Return to Sport after Injury scale
ADL	Activities of Daily Living
AM	Anteromedial
CI	Confidence Interval
EMG	Electromyography
ICRS	International Cartilage Repair Society
IKDC 2000	International Knee Documentation Committee
KOOS	Knee injury and Osteoarthritis Outcome Score
KOS-ADLS	Knee Outcome Survey – Activities of Daily Living Scale
LCL	Lateral Collateral Ligament
LFC	Lateral Femoral Condyle
MCL	Medial Collateral Ligament
MOON	Multicenter Orthopaedic Outcomes Network (United States)
MRI	Magnetic Resonance Imaging
NAR	Norwegian Arthroplasty Register
NKLR	National Knee Ligament Registry
NOA	Norwegian Orthopaedic Association
NPR	Norwegian Patient Register (Norsk pasientregister)
OA	Osteoarthritis
OSTRC	Oslo Sports Trauma Research Center
PCL	Posterior Cruciate Ligament
PL	Posterolateral
PLC	Posterolateral Corner
QOL	Quality of Life
RCT	Randomized Controlled Trial
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index

Papers included

This dissertation is based on the following original research papers, which are referred to in the text by their Roman numerals:

Paper I

Granan LP, Bahr R, Steindal K, Furnes O, Engebretsen L. Development of a national cruciate ligament surgery registry: the Norwegian National Knee Ligament Registry. Am J Sports Med 2008 Feb;36(2):308-15.

Paper II

Granan LP, Bahr R, Lie SA, Engebretsen L. Timing of anterior cruciate ligament reconstructive surgery and risk of cartilage lesions and meniscal tears: a cohort study based on the Norwegian National Knee Ligament Registry. Am J Sports Med 2009 May;37(5):955-61.

Paper III

Granan LP, Lind M, Forssblad M, Engebretsen L. The Scandinavian ACL registries 2004-2007: baseline epidemiology. (Accepted to Acta Orthopaedica)

Paper IV

Magnussen RA, Granan LP, Dunn WR, Amendola A, Andrish JT, Brophy R, Carey JL, Flanigan D, Huston LJ, Jones M, Kaeding CC, McCarty EC, Marx RG, Matava MJ, Parker RD, Vidal A, Wolcott M, Wolf BR, Wright RW, Spindler K, Engebretsen L. Cross-cultural Comparison of Patients Undergoing ACL Reconstruction in the United States and Norway. (Submitted to Knee Surgery, Sports Traumatology, Arthroscopy (KSSTA))

Introduction part 1 – The ACL

Epidemiology

From epidemiological studies we know that 10-19% of acute injuries seen by a Scandinavian doctor in the emergency room are sustained during sporting activity (Arendt and Dick 1995, Bahr et al 2003). Sports participation is the cause in one out of three hospital treated injuries among children (Bahr et al 2003), and in general three out of four acute knee injuries are sports related (Frobell et al 2007). Serious knee injuries (e.g. ACL injuries) are of particular concern (de Loes 1990, Ytterstad 1996). Pivoting sport athletes (e.g. football, basketball, soccer, handball) aged 15-25 years have the highest incidence of ACL injuries, and the incidence is at least tripled in females (Myklebust et al 1997, Myklebust et al 1998). A recent publication by Frobell et al (2007) described an incidence of ACL injuries of 81 per 100,000 inhabitants aged 10-64 years. Data from the NKLR revealed that the annual population incidence of primary ACL reconstruction surgeries was 34 per 100,000 citizens, while the incidence in the 16-39 year age group was 85 per 100,000 citizens (Granan et al 2004).

Embryology

The knee starts to form from a mesenchymal concentration in the fourth week of gestation. This formation process is rapid, and within the sixth week a recognizable knee joint is apparent (Reiman and Jackson 1987). The ACL appears as a condensation in the blastoma at approximately 6.5 weeks (Ellison and Berg 1985), and is well developed by the ninth week (Merida-Velasco et al 1997). After that the ACL will continue to grow, but no major organizational or compositional changes occur after this point (Gardner and O'Rahilly 1968). It begins as a ventral ligament and gradually invaginates with the formation of the intercondylar space. It appears well before joint cavitation and remains extra synovial at all times. Although it changes very little to achieve its final form, it does migrate posteriorly.

Anatomy

The ACL is an intra articular structure that traverses the knee joint attaching to the tibia and femur. The ACL is composed of collagen tissue arranged as longitudinally oriented fibrils ranging from 20 to 170 μm in diameter (Baek et al 1998). Both the cross sectional area and collagen fibrils' diameters are largest in the distal region and decreases as it moves more proximally (Baek et al 1998). The relative amount of collagen in relation to the cross sectional area does not vary significantly between the regions in the ligament (Baek 1998). Collagen fibrils are organized into bundles which make up subfascicular units. These units are surrounded by a thin sheath of loose connective tissue, the endotenon. Bundles of subfasciculi make up a collagen fasciculus, which again is surrounded by an epitenon – a much denser connective tissue than the endotenon. The entire ligament is surrounded by a paratenon, which blends in with the epitenon (Danylchuk et al 1978, Arnoczky 1983). On a histological level the ligament is composed of fibroblasts which are surrounded by a matrix consisting mainly of type I collagen, and near the insertion sites with additions of small amounts of type III and type VI collagen (Amiel et al 1984, Baek et al 1998).

The ACL is usually described as consisting of two discrete bundles (Duthon et al 2006, Giron et al 2006), the AM and PL, the nomenclature corresponds to their anatomical insertion site on the tibia. On the femoral side, the AM bundle originates more proximally and the PL bundle originates more distally with the leg in extension (Chhabra et al 2006, Steckel et al 2007). The divisions are based on the fiber orientation and tensioning characteristics during flexion and extension (Girgis et al 1975, Furman et al 1976, Arnoczky 1983, Harner et al 1999). Norwood and Cross (1977) suggested the presence of a third bundle, the intermediate, this has later been supported by Amis and Dawkins (1991), and Hollis et al (1991). Other authors describe the ACL as one continuous structure (Welsh 1980, Odensten and Gillquist 1985). The conflicting results of studies of the (adult) ACL can be at least partially explained by the variation in bundle orientation in different degrees of knee flexion, making it difficult to visualize both bundles in any single transverse histological section (Feretti et al 2007). In addition, the vascular connective tissue flows into and out of the ligament, further complicating the anatomic picture (Feretti et al 2007).

The bundles relative size have varied across various studies, but Girgis et al (1975), Harner et al (1999) and Palmer (1938) found no significant difference between the two bundles. Disregarding the discrepancies in anatomic description, and considering a view from a functional standpoint, the ACL demonstrates varying tensile characteristics across its width. Edwards et al (1999) demonstrated the following elongation behavior of the ACL bundles: The strain pattern of the intact ACL's AM bundle exhibited an initial shortening from 0° to approximately 30° of flexion, followed by lengthening from 30°-120° of flexion, and thus reaching its maximal strain at 120°. Net lengthening from the baseline length at 0° was only observed in the range of approximately 70°-120° of flexion. The strain pattern of the intact ACL's PL bundle exhibited shortening over the entire range (0°-120°) of flexion, and reaching minimal strain at full flexion. The PL bundle shortened approximately two thirds of its maximal length from 0°-50° of flexion.

The relative position of the AM bundle and the PL bundle varies with the flexion of the knee. In extension, the two bundles are parallel (Chhabra et al 2006). In flexion, the femoral insertion site of the PL bundle moves anteriorly, and the two bundles are crossed (Chhabra et al 2006). In flexion, the AM bundle tightens as the PL bundle loosens (Amis and Dawkins 1991). In extension, the PL bundle tightens and the AM bundle loosens (Amis and Dawkins 1991). The PL bundle tightens during internal and external rotation of the knee (Chhabra et al 2006).

The insertion sites of the ACL are marked by a gradual transition, within a depth of less than one millimeter, of relatively flexible ligament tissue that merges into rigid bone. Electron and light microscopic evaluation of this region performed by Cooper and Misol (1970) described four morphologic zones, each with clearly defined characteristics. Zone 1 is the ligament tissue, primarily made up of collagen; zone 2 represents a mix of collagen blended with unmineralized fibrocartilage; zone 3 contains mineralized fibrocartilage; and zone 4 represents the subchondral bone. This anatomy is thought to be mechanically advantageous, allowing for force dissipation and having implications with regard to ligament failure modes (Cooper and Misol 1970, Noyes et al 1974).

The ACL fascicles course in a spiral rotation and are described as fanning out as they approach their tibial insertion (Smith et al 1993). They traverse from the femoral

attatchment in a distal, anterior, and medial direction (Girgis et al 1975, Arnoczky 1983). Although the bundles were indeed parallel in extension, flexion of the joint resulted in a crossing of the PL bundle over the AM bundle (Girgis et al 1975, Arnoczky 1983). The reported average length of the ACL ranges from 22 mm to 41 mm, with a mean of 32 mm (Dienst et al 2002).

The ACL has attachment sites on both the femur and tibia. The femoral insertion site, a circular area encompassing averagely 113 mm² (Harner 1999), originates from the posteromedial aspect of the intercondylar notch on the lateral femoral condyle. Steiner et al (2008) published a review were he consolidated the findings of Girgis et al (1975), Odensten and Gillquist (1985), Colombet et al (2006), Mochizuki et al (2006) and Heming et al (2007) and emphasizing the more recent data, found that the ACL femoral insertion has an approximate average length of 18 mm, width of 10 mm, and a separation of up to 4 mm from the articular cartilage. The tibial insertion site, an oval area encompassing averagely 136 mm² (Harner et al 1999), is on the intercondylar eminence of the tibia but does not attach to either the medial or lateral tubercles of the intercondylar eminence (Girgis et al 1975, Morgan et al 1995, Heming et al 2007). From more recent studies there have been reported that the tibial insertion lengths varies from 15 to 18.5 mm and widths from 10 to 13 mm (Odensten and Gillquist 1985, Morgan et al 1995, Heming et al 2007), giving an oval attachment with an approximate length of 18 mm and approximate width of 10 mm as a consolidated overall result (Steiner et al 2008). Although general agreement exists on the size and shape of the tibial insertion, there is still debate over best method to identify its anterior and posterior boundaries (Steiner et al 2008). Both insertion sites are more than 3.5 times larger than the cross sectional area of the ligament midsubstance, which measure averagely just below 40 mm² (Harner et al 1999).

Both the cruciate ligaments are covered by a synovial fold that originates at the intercondylar notch's posterior inlet and extends to the ACL's anterior tibial attachment site, resulting in the cruciate ligaments being both intra articular and extra synovial at the same time (Arnoczky 1983). The ACL is mainly supplied by vessels originating from the middle genicular artery which leaves the popliteal artery and directly pierces the posterior capsule (Arnoczky 1985). Branches, that form a periligamentous plexus, enter the synovial membrane at the junction of the joint capsule distal to the infrapatellar fat pad (Ellison and Berg 1985, Kennedy et al 1974). The ACL is surrounded by a synovial plexus along its entire length. Smaller, connecting branches penetrate the ligament and anastomose with a network of endoligamentous vessels that are oriented in a longitudinal direction and lie parallel to the collagen bundles within the ligament (Arnoczky 1983, Ellison and Berg 1985).

The majority of neural structures have been found in the subsynovial layer and near the insertions of the ACL (Reiman and Jackson 1987). The posterior articular nerve, a branch of the tibial nerve, is the major neurobundle (Kennedy et al 1974); it arises from the tibial nerve in the popliteal fossa, wraps around the popliteal artery and vein, penetrates the posterior capsule, and forms the popliteal plexus. Branches from this plexus course through the synovial lining of the cruciate ligaments, follow the course of the blood vessels, and extend as anterior as the infrapatellar fat pad. Neurotracer studies performed by Hogervorst and Brand (1998) revealed the existence of very few receptors in the ACL.

Further studies by Krauspe et al (1995) narrowed it down to a maximum of 17. These numbers decrease with age and disease. The receptors found are primarily Ruffini receptors and free nerve endings that are thought to function as stretch receptors and nociceptors, respectively (Hogervorst and Brand 1998). Free nerve endings may also serve as local effectors by releasing neuropeptides with vasoactive function, thus having modulator effect in normal tissue homeostasis or in remodeling of grafts (Hogervorst and Brand 1998). In 1998 Hogervorst and Brand (1998) stated that convincing evidence on the direct effects of mechanoreceptors of the ACL on electromyographic activity of muscles surrounding the knee was missing. Later it has been demonstrated that low intensity electrical stimulation of the intact ACL in humans could induce clear cut excitations or inhibitions of the isometrically contracting quadriceps and semitendinosus muscles (Dyhre-Poulsen and Krogsgaard 2000). Even so, Sjölander et al (2002) concluded in a review that to what extent the EMG effects are mediated through interneuronal pathways directly to the skeletomotoneurones, or indirectly via reflex actions on the γ-muscle spindle system, is not possible to elucidate using only EMG registration technique.

Biomechanics

The ACL functions as the primary restraint to anterior translation of the tibia in relation to the femur (Butler et al 1980, Fukubayashi et al 1982) and as a secondary restraint to internal-external rotation, varus-valgus angulation and combinations thereof (Markolf et al 1976, Markolf et al 1990, Marder et al 1991, Markolf et al 1995, Fleming et al 2001, Kanamori et al 2002). The ACL has an average cross sectional area of 44 mm². The ultimate tensile load measured in young ACLs (22 to 35 years) is 2160 ± 157 N and a stiffness of 242 ± 28 N/mm, while for older ACLs (60 to 97 years) the numbers are 658 ± 129 N and 180 ± 25 N/mm, respectively (Woo et al 1991). Normal daily loads on the ACL are estimated to approximately 20% of its load capacity (Frank and Jackson 1997, Martelli et al 1998). Age is an important factor in the strength aspect of the ACL; older ACLs fail under lower loads than younger ACLs do (Woo et al 1991). The forces in the intact ACL range from approximately 100 N during passive knee extension (Markolf et al 1996) to about 400 N with walking and reach, and up to 1700 N with cutting and acceleration-deceleration activities (Butler et al 1985, Nogalski and Bach 1994). Beynnon and Fleming (1998) presented a review of in vivo strain patterns in the intact ACL during a variety of activities and exercises. The most crucial variables influencing ACL strain were the knee position and the dynamic interaction of muscle activity. Increased strain was seen with increasing knee extension. Activities that produced isolated quadriceps activity led to the highest ACL strain, contrary to the isolated hamstring activity that produced the lowest levels of ACL strain. Co contraction of the hamstrings during closed chain extension activities provided a moderating effect to the strain produced by isolated quadriceps activity seen in open chain activities. Nevertheless, in the real patient, the ACL probably carries loads approaching its failure capacity only during relatively unusual combinations of loading of the knee by external forces or muscles (Frank and Jackson 1997).

Injury mechanisms

According to Bahr and Krosshaug (2005) injury mechanisms is poorly defined in the literature. They propose a comprehensive model that includes information on different levels when an injury occurs. Their model includes a full description of the mechanisms for a particular injury type in a given sport. In such a model the inciting event of an injury could be grouped into four categories and described as: 1) vital aspects of the playing/sports situation; 2) athlete and opponent behavior; 3) gross biomechanical characteristics (whole body) and 4) detailed biomechanical characteristics (joint/tissue). Further more they conclude that until a complete description is available which includes information on all causative factors, it may be difficult to predict which factors are the most suitable to influence through interventions.

Independent of the model proposed by Bahr and Krosshaug (2005) one may divide injury mechanisms into contact and non contact maneuvers. Contact type mechanisms are fairly easy to understand and interpret since the blow to the knee (often from the side or front) usually is obvious. These mechanisms often produce injuries to multiple structures in the knee joint. The motion sequence of non-contact injury is usually a sharp deceleration associated with or without a change of direction; landing on one or two legs; hyperextension of the knee; sharp, pivoting motion of the body around a planted leg or varus collapse of the knee (Boden et al 2000). A review by Quatman and Hewett (2009) concluded that non-contact ACL injuries almost certainly occur during complex, multiplanar knee joint load states during multiplanar sports movements.

Diagnosis

The Lachman test (Torg et al 1976) is the most sensitive and specific clinical investigation to diagnose pathological anterior tibial translation in ACL instability (Scholten et al 2003). In a recent meta-analysis by Crawford et al (2007) the pooled sensitivity and specificity of the Lachman test were 85% and 94%, respectively. For the Pivot shift test the specificity was 98%, but the sensitivity only 24% (Crawford et al 2007). But a recent study by Frobell et al (2007) stated that the lack of agreement between clinical instability – measured as anterior-posterior knee laxity by the Lachman test and/or the drawer sign – and MRI findings indicates that a large group of patients with severe knee injuries may not be diagnosed correctly, and thus not receives optimal treatment. MRI is accurate for discriminating complete ACL graft tear from partial thickness tear and intact graft (Horton et al 2000). According to a review by Sandberg et al (1987), MRI had a sensitivity of 86%, a specificity of 95%, and an accuracy of 93% for an ACL tear, as confirmed by arthroscopy. Thus, it is important to remember that the MRI is inaccurate in nearly 10% of the cases, and for these patients the examiners' clinical experience is crucial After all, ACL rupture is a clinical diagnosis and experience indicates that the Pivot shift test is the best, performed by an experienced examiner. The pivot shift motion is the major symptom in ACL insufficiency. It represents a sub-luxation of the lateral femoral condyle behind the lateral tibial plateau, caused by an anterior rotation of the lateral tibia (i.e. internal rotation of the tibia). Finally, it is claimed by Frobell et al (2007) that every second patient with an acute ACL injury risks being sent home from the orthopaedic emergency unit diagnosed as an uncomplicated knee sprain, if not further assessed by MRI in the sub acute phase.

ACL tears rarely occur in isolation but are in at least 50% of the cases associated with other ligament sprains, meniscus tears, articular cartilage injuries, bone bruises, and sometimes intra-articular fractures (Beynnon et al 2005a, Beynnon et al 2005b). In addition to the acute events associated with a joint trauma, the lack of a functionally normal ACL or meniscus will change the static and dynamic loading of the knee, generating increased forces on the cartilage and other joint structures (Dye 1996, Andriacchi et al 2004, Song et al 2006). As a result, additional lesions commonly occur (or become symptomatic) with time in the ACL injured knee and, in particular, in the meniscus (Dunn et al 2004, Fithian et al 2005, Meunier et al 2007).

To prevent missing posterior rotational instability of the lateral compartment, due to failure of the posterolateral corner, which may result in recurrent instability after ACL reconstruction (Carson et al 2004) the following standard knee investigation is recommended (Krogsgaard 2007):

- Tests for varus and valgus stability (with 0º and 30º of flexion)
- The Lachman test
- The anterior and posterior drawer test
- The Pivot shift test (not in acute cases)
- The posterior sag test
- The external rotation test (in 30º, 60º and 90º of flexion)

Prognosis

The natural history of the ACL deficient knee has not been characterized by a well designed prospective cohort study, leaving us with uncertainty when describing the complete natural history of this injury. Although the majority of patients cannot return to high level activities after ACL injury because of continual episodes of knee giving way (non copers) (Eastlack et al 1999), a small percentage make a full, asymptomatic return to all pre injury activities (copers) without surgery (Daniel et al 1994, Eastlack et al 1999). Nevertheless, a common consensus exist that ACL injury can result in long term absence from work and sports, and dramatically increases the risk of long term sequelae such as abnormal joint dynamics and early onset of degenerative joint disease, i.e. OA (Beynnon et al 2005a, Myklebust and Bahr 2005, Roos 2005, Thelin et al 2006). Despite massive research efforts, there is still lacking evidence to suggest that reconstructive surgery of either menisci or cruciate ligaments decreases the rate of post traumatic OA (Beynnon et al 2005a, Myklebust and Bahr 2005). The reported rates of radiographic signs of OA after an ACL injury vary between 10% and 90% at 10 to 20 years after the ACL injury, regardless of treatment choice (Gillquist and Messner 1999, Lohmander and Roos 2004, Lohmander et al 2004, Beynnon et al 2005a, Myklebust and Bahr 2005, Shelbourne and Gray 2009). Stating a mean OA rate is difficult because of the great variability of the reported results, but an overall long-term mean of more than 50% may be suggested (Lohmander et al 2007). A recent systematic review by Øiestad et al (2009) found that previously reported prevalence rates of knee OA at a minimum of 10 years after ACLR have been too high. They found a 0-13% prevalence rate of knee OA in individuals with isolated ACL injuries, and a prevalence rate of 21-48% in individuals with combined

injuries. Roos et al (1995) have previously shown that subjects with ACL injury and posttraumatic OA are, on average, 15 to 20 years younger than patients with primary OA when they seek medical advice for their symptoms and when their joints show radiographic evidence of OA.

In line with previous studies (Butler et al 1980, DeHaven 1980, Noyes et al 1980) Frobell et al (2007) found that at least every second ACL injury is associated with a meniscal injury. Despite this a recent paper by Drogset et al (2006) suggested that early surgical intervention would be beneficial since the knees at an early stage had less cartilage damage compared to knees with late surgery. At 16 years follow up only 11% of the patients that had early surgical intervention had developed OA, while 4% had developed OA in the contra lateral knee. It is important to emphasize that only 50% of these patients had been through radiographic investigations. Furthermore, they had a low activity level compared to those with high activity level and pivoting activities which had approximately 50% OA. Nevertheless, the systematic review by Øiestad et al (2009) found that meniscal injuries and meniscectomy are well-documented risk factors for the development of knee OA at a minimum of 10 years after ACL injury. They also found that factors such as ACLR, age, obesity, knee joint laxity, performance on hop tests, and loss of knee extension are still not sufficiently documented to be considered as risk factors. Eitzen and colleagues (2009a) have in a prospective cohort study documented that two years after surgery, individuals with preoperative quadriceps muscle strength deficits on the injured side above 20% still have abnormal muscular asymmetry. A recent study by Meuffels et al (2009) found similar performance between conservatively treated and surgically treated high level athletes at 10 years after ACL injury. Except for higher objectively measurable instability for the conservative group, there were no statistical difference with respect to OA, meniscal lesions, activity level, and objective and subjective functional outcome. Neuman et al (2008) found that in patients with ACL injury willing to moderate their activity level, initial treatment without ACLR should be considered due to favorable long-term outcome regarding incidence of radiographic knee OA, knee function and symptoms, and need for ACLR. Chaudhari et al (2009) found that there are anthropometric differences between the knees of subjects with a non contact ACL injury and those without an ACL injury, and suggests that ACL volume may play a direct role in non contact ACL injury. Posthumus et al (2009) found an association between ACL ruptures in an independent population and a specific genetic polymorphism. And propose that this sequence variant be the first specific genetic element to be included in multifactorial models developed to understand the etiology and risk factors for ACL rupture. A recent study by Lohmander et al (2007) found that the KOOS (see Part 2 for details) subscales Function in Sport and Recreation and knee related QOL showed marked changes over time, suggesting that monitored by valid patient-administered outcome measures, results of ACL rehabilitation and/or surgery are at best at 1 to 2 years of follow-up and then gradually deteriorate over time.

Recent studies show that it may be possible to reduce the incidence of knee injuries by using various training programs (Hewett et al 1999, Wedderkopp et al 1999, Heidt et al 2000, Junge et al 2002, Myklebust et al 2003, Mandelbaum et al 2005, Olsen et al 2005, Gilchrist et al 2008, Pasanen et al 2008, Soligard et al 2008). However it is not known which program component is the key ingredient in preventing knee injuries or how they work (Bahr and Krosshaug 2005). An interesting finding is presented by Liederbach et al

(2008), they found a low incidence of ACL injuries among elite ballet and modern dancers compared with published literature on athletes from other sports that involve jumping movements, and no significant difference was found between genders. This may be due to emphasize on lower extremity alignment, and jump and balance training (Liederbach et al 2008). At least in part, our ability to target and improve current prevention programmes is limited by an incomplete understanding of the causes of injuries (Bahr and Krosshaug 2005). Nevertheless, Quatman and Hewett (2009) states that according to the biomechanics of non-contact ACL injuries, preventive multiplanar training exercises should focus on lowering risky biomechanics in multiple planes such as large knee valgus, internal/external knee rotations and shallow knee flexion angles. They also propose that sex-specific mechanisms of ACL injury may occur.

Indications for treatment

Beynnon et al (2005a) recently stated that because the true natural history of the ACL deficient knee and consequently the ultimate outcome of ACL reconstruction are unknown, rigid criteria for patient selection for surgical versus non surgical reconstruction have not been established. The rationale for non surgical treatment assumes that the ACL deficient knee may function reasonably well under certain circumstances and that reconstruction does not necessarily prevent the untoward sequela of OA. Patients with a complete ACL tear may be treated satisfactorily, even with advanced OA of the involved knee. The rationale for surgical treatment is based on the observation that the ACL is vital for knee function, that ACL deficient knees frequently degenerate, and that surgical reconstruction of the ACL can succeed in restoring normal function. A nearly universally accepted indication for ACL reconstruction is a high risk lifestyle requiring heavy work, sports, or recreational activity and repeated episodes of giving way (pivot shift episodes) despite proper rehabilitation. Nevertheless, Spindler and Wright (2008) categorically states in a clinical practice article in the New England Journal of Medicine in November 2008 that "surgical treatment is indicated if the patient has a sensation of instability in normal activities of daily living or wants to resume activities that involve cutting and pivoting, (…) [or] occupations (…) [that] require an ACL-stabilized knee." In 2008 Kostogiannis et al (2008) published a cohort study with 15 years follow up regarding clinically assessed knee joint laxity as a predictor for ACLR, with patient age ranging from 14 to 41 at the time of injury. They found that a positive Pivot shift test at 3 months after injury in an awake patient is the strongest predictor for the future need for ACLR, and that a normal Pivot shift test at 3 months indicates a low risk for later ACLR and is characteristic for copers. Clinical tests for knee laxity in the acute phase were not a good predictor of the need for later ACLR. The latter is also supported by Eitzen et al (2009b). Patients may be classified as rehabilitation versus early surgical candidates using a screening examination developed at the University of Delaware (Fitzgerald et al 2000). This classification algorithm was used in a study (Hurd et al 2008) where patients were categorized as non copers or potential copers based on giving-way episodes, timed hop, global rating of knee function, and KOS-ADLS (Irrgang et al 1998) scores. The algorithm uses a group of variables that collectively capture neuromuscular function and predict patient outcomes, and such clinical tests may therefore be useful in guiding in individualized patient management after ACL injury (Hurd et al 2008). A recent article by Swirtun et al (2006) revealed that

patients who chose early reconstruction (< 6 months post injury), chose surgical treatment for reasons based on assumptions of future problems associated with the knee injury, whereas patients who chose late reconstruction, chose surgical treatment for reasons based on experience of knee function.

Non operative treatment of ACL tears in adults

When considering the scientific basis for non operative treatment of ACL tears there is considerable amounts of information based on case series, comparisons of case series and cross sectional studies, but also the additional problems with bias (i.e. selection bias, information bias and confounders). Four Swedish RCTs (Odensten et al 1985, Sandberg et al 1987, Andersson et al 1989, Andersson et al 1991) are available concerning non operative ACL treatment versus ACL repair or repair with augmentation. Repair is no longer a preferred surgical treatment due to inferior surgical outcomes. One of the studies above (Sandberg et al 1987) found no differences in outcomes compared with non operative treatment. This may be attributed to the use of cast rather than active rehabilitation. The other three (Odensten et al 1985, Andersson et al 1989, Andersson et al 1991) found that superior results were achieved in patients with ACL repairs with augmentation using the iliotibial band, compared with those with repair alone or non operative treatment. A 15-year follow-up of the Andersson and colleagues 1989-study revealed rather similar results in both groups regarding OA, knee function, and activity level, but 1/3 of the non surgically treated subjects underwent later ACL reconstruction for instability (Meunier et al 2007).

There is general agreement that over the course of years after the trauma, the injured knee, reconstructed or not, will be submitted to abnormal loading patterns in everyday activities as well as in sports, significantly increasing the risk of OA (Lohmander et al 2007). A report based on review of an administrative database (The US Army Total Army Injury and Health Outcomes Database (TAIHOD)) suggested that ACLR in a young and active population provided some protection against additional procedures, compared with those not reconstructed (Dunn et al 2004).

To date no RCTs that compare bone-patellar-tendon-bone or multi-strand hamstring autograft ACL reconstructions with non operative treatment has been published. Therefore, ultimately the doctor and/or surgeon must evaluate each patient individually and inform them about all possible advantages and risks of any treatment method proposed. Some guiding in this process is obtained in a review by Lewek et al (2003), where an algorithm that includes screening tests to determine which patients with an ACL injury that may be candidates to non operative treatment is described. Nevertheless, patients classified as non-copers at the initial examination have substantial potential to regain dynamic knee stability at one year follow-up, and should not be excluded as rehabilitation candidates (Moksnes et al 2008b) since it is likely that patients receiving non-operative treatment have at least as good results as the ACLR one year post-injury (Moksnes and Risberg 2009). On the other hand we do not know if the copers also have less cartilage lesions and meniscal tears, only that they are pivoting less.

Timing of ACL reconstruction

No consensus exists on the ideal timing for ACL reconstruction. Beynnon et al (2005a) claim that after reviewing the literature on this subject, it appears that the time interval from ACL injury to reconstruction is not as important as the condition of the knee at the time of surgery (i.e. the knee should have a full range of motion with minimal effusion; the patient should have minimal pain and be mentally prepared for the reconstruction and rehabilitation after surgery.). And they conclude that there are no absolutes as to when ACL reconstruction should be performed. Despite this, a retrospective study that claims that ACL reconstructions should be carried out within 12 months of injury to minimize the risk of meniscal tears and degenerative change has been published (Church and Keating 2005). Even so it is important to emphasize, as mentioned above, that Drogset et al (2006) found only 11% of patients with developed OA at 16 years follow up when ACL surgery were performed no more than 10 days after injury, even when accompanied with long post operative immobilization and slow rehabilitation. Papastergiou et al (2007) recommend that ACLR should be carried out within three months after injury to minimize the risk of developing secondary meniscal tears. Yoo et al (2009) found in a case series that ACL deficient knees with or without a medial meniscal lesion can suffer subsequent damage to the medial meniscus, and this should be expected if ACLR is delayed beyond six months after initial MRI. In the present thesis, paper II concludes that early surgery may be recommended, as a consequence of its association with fewer meniscal tears and cartilage lesions.

Introduction part 2 – The NKLR

Background

National quality registries have been used in several medical specialties to improve health care in Scandinavia (Kjaerheim 1999, Lichtenstein et al 2002, Akesson 2003, Heaf 2004, Sokka 2004, Kallen 2005, Pahlman et al 2005, Ohm and Derom 2006), including Norway (Kjaerheim 1999, Irgens 2000, Bergem 2002, Kvien 2003). Because of the inferior clinical results associated with some hip prosthesis designs in the early 1980s (Havelin 1995), the nationwide Norwegian Hip Arthroplasty Register (NAR) was established in 1987 with implant revision as the main endpoint (Havelin et al 1993). The aim was the early detection of inferior results caused by implants, cements or surgical techniques (Havelin et al 2000, Furnes et al 2002). In 1994, the registry was expanded to include all joint replacements (Havelin et al 2000). In 1995, two papers (Havelin et al 1995a, Havelin et al 1995b) described the detection of inferior implants at an early stage, a finding only possible through registry studies.
The NAR is based on a simple reporting system (approximately one minute is required to complete a single-page registration form) and the hospitals are provided with continuous feedback from the registry (Havelin et al 2000). These two factors are believed to explain why the compliance rate of nearly 100% has not declined during 20 years of operation (Havelin et al 2000, Espehaug et al 2006). Immediately after each operation, the surgeon completes the registration form, which is mailed to the NAR office (Havelin et al 1993). Patient identification and the different procedures, including the type of implant and cement used, are specified on the registration form. Feedback is given as annual national reports. In addition, each hospital receives a report on its own activities and results, which can be compared with the national average. A wide range of studies have been published based on the NAR database (Havelin et al 2000).

In contrast to joint replacement surgery, where national registries have been established in Norway, Sweden (1975), Finland (1980), Denmark (1995), Australia (1998), Hungary (1998), New Zealand (1998), Scotland (1999), Canada (2000), Italy (2000), Romania (2001), England and Wales (2003), Slovakia (2003), and Spain (2004), no national prospective surveillance system exists for monitoring the outcome of knee ligament surgery in a predefined population. Evidence from the Scandinavian joint replacement registries indicates that a national knee ligament registry could be highly beneficial (Havelin et al 1995a, Havelin et al 1995b, Herberts and Malchau 1997, Malchau et al 2002). First, treatment outcome can be improved through feedback to the hospitals and surgeons from the registries. Second, there are still several unresolved issues related to cruciate ligament surgery and postoperative rehabilitation methods. Some of these can and should be addressed by conducting properly designed RCTs. However, because of practical, financial or other restraints, such studies are often not possible. Also, some questions can only be answered by large cohort studies. This can include the detection of procedures and devices that result in premature failure. Third, a large cohort study can be used to identify prognostic factors associated with good and poor outcomes.

This background served as the impetus for designing the Norwegian NKLR. A working group was established with members from NAR and the OSTRC in 2002. The group designed the registry, constructed forms, performed a pilot study, planned the logistics,

and contacted the hospitals. The NKLR is owned by the NOA, and a steering committee with six members is appointed jointly by NOA and OSTRC. Since the official start on June 7, 2004, the steering committee has been responsible for the budget, planning, continuous evaluation of the data set, and for reviewing the results on a regular basis.

Objectives

It is the NKLR's main intention to contribute to quality control and improvement of the surgical cruciate ligament procedures. This may be done through establishing evidence based national guidelines and protocols for surgical procedures and rehabilitation. To understand the importance of reported failures, we need to know the actual number of reconstruction and revision surgeries that are performed. NAR has previously provided accurate data of sufficient quality. The NKLR has calculated that if 14 patients with one specific fixation device fail, this may be considered a failure of that specific device. This will enable the NKLR to give early warnings on procedures and devices as well as identify prognostic factors.

The NKLR is providing information for the orthopaedic community at regular intervals on the outcomes of surgical treatment of the cruciate ligaments with different methods. The hard end points are clear and unequivocal, i.e. revision reconstruction and total knee replacement. Causality of failure may not be sufficiently and accurately documented in the NKLR, but it will provide information as to where there may be potential problems and direct future analysis and studies toward these areas. Since the NKLR will provide real time information and thus can be analyzed on an ongoing basis, it has the potential to reveal problems long before they would be reported by traditional methods (e.g. RCTs). This will undoubtedly benefit all interested parties, not at least the patients.

Design

The NKLR is designed to collect information prospectively on all cases of cruciate ligament reconstruction surgery, and subsequent knee joint surgeries. To be included in the cohort, a patient should be a resident of Norway undergoing primary or revision reconstruction surgery for an ACL and/or PCL injury at a Norwegian hospital. In addition, the NKLR also records all surgical procedures to a knee joint that has previously undergone primary or revision ACL and/or PCL reconstruction surgery.

Participation is voluntary, and all patients are asked to sign an informed consent form before surgery. The consent form contains information about the NKLR, the type of information recorded, data protection, the procedure for follow ups and informs the patient that he or she may be invited to participate in research projects at a later stage. The patients are also asked to complete a validated knee outcome score form (Roos et al 1998a, Roos et al 1998b, Roos and Lohmander 2003), the KOOS (appendix 1-4). At any time, any patient can withdraw their contribution to the NKLR without stating a reason; previous, present and/or future contributions. Confidentiality is assured for patients and individual surgeons.

Orthopaedic surgeons report the patient's social security number on the paper-based registration form (appendix 5 and 6) to identify the patient. By using this identification, information on outcomes (revision reconstructions and other knee surgeries) can be linked to the baseline information (primary cruciate ligament reconstruction surgery)

even if later procedures are performed elsewhere. With this kind of system, and when all hospitals, clinics and orthopaedic surgeons are contributing and where data on patients' knee arthroplasties, deaths or emigrations are available, the follow up of patients can be nearly complete.

Classification, coding and data systems

Index side, date of surgery, performed procedures, choice of graft, fixation devices, and systemic antibiotic prophylaxis are examples of reported information. Cartilage lesions are graded according to the ICRS (Newsletter ICRS 1998). The NKLR collects separate information on fixation devices both for grafts and synthetic fixation of meniscal lesions. All fixation devices have been classified according to the three different variables: inside or outside of channel; material used (metal, plastic or bioabsorbable); type (e.g. interference screws, pins). These variables are registered along with the name of the manufacturer and the products reference number (not the LOT number). As a result of this detailed information, the results for the different implants can be calculated separately. To ensure accurate information on the implant, the orthopaedic surgeons use the unique bar code stickers with the catalogue numbers of the implants supplied by the manufacturers. The orthopaedic surgeons Torbjørn Strand and Knut Fjeldsgård have coded the implants in the registry. As of today all coding updates are performed by Knut Fjeldsgård.

The NKLR's server is located at Helse Vest IKT AS and is run from there. They are also responsible for the back ups.

End points

The registry makes use of both objective and subjective end points. Similar to NAR, the hard end points are revision surgery after cruciate ligament surgery and total knee replacement. Unlike NAR, the NKLR has included routine follow-ups on all patients at two, five and ten years postoperatively using KOOS as a soft end point. The follow-up forms include three additional questions to increase the detection rate of patients with unreported poor outcomes (see appendix 3 and 4). The KOOS form is completed by the patients preoperatively and used as the patients individual baseline score. Some surgeons claim that the patients' mental status differs on the day of surgery, and that this may be due to them exaggerating complaints too convince themselves that surgery is the best choice of treatment. This argument is not supported by Bryant and coworkers (2008), they found that patients undergoing surgery for the treatment of a chronic knee injury (e.g. ACL injury) can provide an accurate self-assessment of their quality of life, general health, and functional status on the day of surgery (Bryant et al 2008). Further on, they also found that investigators can improve the efficiency of data collection for clinical studies for chronic knee injured patients, with no expected loss of statistical power, by obtaining self-assessments on the day of surgery. This finding supports the suggested routine from the NKLR, to let the patients complete the KOOS on the day of surgery or the day before.

KOOS

The KOOS form is a knee specific instrument, developed to assess patients' opinion about their knee and associated problems, and is intended to be used for knee injuries that can result in post traumatic OA; i.e. ACL injury, meniscus injury, chondral injury, etc. It is meant to be used over short and long time intervals; to assess the magnitude of change over time. KOOS can be used to assess groups and to monitor individuals. The questionnaire, validated for several languages, and a scoring manual are available at the KOOS website http://www.koos.nu. It includes 42 items in 5 separately scored subscales: pain (9 items), other symptoms (7 items), function in ADL (17 items), function in Sport and Recreation (5 items), and knee related QOL (4 items). Each item is responded to by marking one of five response options on a Likert scale. The WOMAC OA Index LK 3.0 (Bellamy et al 1988) items are included in the first three KOOS subscales. The KOOS form will at the time for follow-ups be dispatched from the NKLR secretariat.

The KOOS form did not exist in a Norwegian translation when the preliminary work on the registry was performed. Since the KOOS form already existed in English and Swedish two separate translations into Norwegian were arranged; one of the authors did one translation from English to Norwegian, and the translation from Swedish were done by a former researcher at the Norwegian School of Sport Sciences, who is bilingual in both Norwegian and Swedish. The translations were compared, and due to only minor differences in the use of synonyms the NKLR chose a wording as close to the Swedish translation as possible. This is due to the fact that the creators of the KOOS form are Swedes, even though the first form was made in English. This procedure is not satisfying as a validation process (Guillemin 1993).

Later on the KOOS form has been validated by researchers at NAR. KOOS was translated from the Swedish version by two orthopaedic researchers. The choice of using the Swedish version was based on the assumption that cultural differences between the two neighbor countries would be minimal due to similarities in language and lifestyle. The translation was checked by two bilingual orthopaedic surgeons (Swedes with permanent address in Norway). The form was tested on knee arthroplasty patients to clarify potential misinterpretations. Then the NAR and the NKLR versions were compared, minor adjustments were done, and the translators agreed upon a common translation. The final validated Norwegian version is named KOOS Norwegian version LK 1.0, and is available from the KOOS website.

Selection of a minimal set of necessary data

The NKLR is built on experiences from the NAR. When NAR was started, a high number of different procedures were utilized, a situation fairly identical to what the NKLR experienced when it was established. Little knowledge was available on the epidemiology of pre operative, surgical and post operative procedures for cruciate ligament injuries in Norway, and this led us to perform an epidemiological study in February 2003. A questionnaire, which contained questions regarding surgical frequencies, surgical procedures and rehabilitation methods in relation to ACL surgery conducted in 2001 and 2002, was mailed to every Norwegian hospital and clinic with a surgical division, and we were able to obtain answers from all of them. The results from this study were published in 2004 (Granan et al 2004), and concluded that the incidence

of ACL injuries was higher than previously estimated; that there is a probable increase in the number of surgical interventions due to ACL ruptures in Norway; and that there still is considerable variation in surgical procedures and choice of post operative rehabilitation methods among the different hospitals in Norway.

These findings and experiences combined with our original intention that collection of data should be motivating for the orthopaedic surgeon, rather than exhausting. Although it is desirable to collect as much information as possible, in large multi centre registries, there appears to be an inverse relationship between the amounts of information asked for and the quality of data delivered (Robertsson 2007). The real value of information depends on the completeness and accuracy of the data (Robertsson 2007). Consequently, the data sets were minimal and after pilot testing at three hospitals, agreed limited to the variables seen on the registration form. The data items recorded are a minimal set suited for paper-based or web-based reporting system not to exceed one page. The items were chosen based on the following three criteria: Can the question addressed be clearly specified and justified? Is the question clinically relevant? Can the item be completed post operatively while dictating the surgery notes, not needing to seek information from other sources?

Since the real value of information from the registration form is depending on the completeness and accuracy of the reported data it is important not to get too ambitious on behalf of the research and thus make the data set too extensive. This will only return incomplete data and make the information useless. Additionally, if the data are to be compared with other registries it is essential to use a core minimum data set that has been agreed upon. The already performed compliance studies (paper I) suggest that the reported number of primary ACLR to the NKLR is reliable. However, regarding completeness (i.e. if the same information is reported to the NKLR as written in the surgical logbooks), no studies have been carried out so far.

Collection of data

The registration form collects information on the details of surgery. One form is completed for each knee joint undergoing surgical treatment. Similar to NAR, the form is completed by the surgeon immediately after the surgery has been performed.

One copy of the registration form is sent to NKLR and the original is retained in the patient's hospital chart. On arrival at the NKLR, the KOOS and registration forms are checked for completeness and entered into a computerized data management system. This is developed, by Kjersti Steindal at the NKLR and NAR, as an Oracle database (Oracle Corporation, Redwood Shores, California, US) with clerical and electronic data checks, as well as automated coding and reporting facilities. After registration, the data is further checked to secure the quality, eliminate possible duplicates and illogical combinations in the form, and ensure conformity between registration and KOOS forms.

A copy of the registration form is returned to the hospital if the form is incomplete (e.g. if essential data such as the date of operation or the social security number is missing). If the form is not returned after one reminder or the data cannot be found, the form is marked as incomplete and labeled "missing" for the missing data; thus retaining the possibility of using incomplete forms in the analysis. To limit the amount of missing data

there are printed directions on how to fill in the form on the back of the registration form, in addition to explanations to the questions on the front page. This additional information is based on the pilot study and our experience on what usually is misunderstood when filling in the form.

The KOOS form is not returned to the patient if incomplete. Missing data are treated according to the guidelines for KOOS calculation (Roos et al 1998a). Patients that do not respond will receive a reminder after three months, also explaining the importance of their reply to the NKLR and validity of the registry's database. In addition the NKLR will offer different ways of returning the completed KOOS forms, such as regular mail and internet, as an attempt to ensure a high compliance rate.

Research and information

Requests for data from the NKLR for research and clinical use are encouraged, and data files are returned to the surgeon or hospital in question after approval of a written request addressed to the steering committee. Only the official hospital contact can ask for patient-identifiable information from his/her own hospital. Some legal restrictions exist, primarily the combination of the NKLR with other population based registries in Norway. Requests for more extensive data for research projects also require a written application to the steering committee. If external researchers wish to combine data from the NKLR with their own data files, specific approval is required from the Data Inspectorate and the appropriate Regional Committee for Medical Research Ethics.

Descriptive national data are provided in an annual report, which is sent to all members of the NOA, all hospitals performing cruciate ligament surgery, and to the health authorities. This report is also published on the joint website of NAR and NKLR (http://www.haukeland.no/nrl). In addition, each participating hospital will receive descriptive statistics and outcome data for their own hospital, which they can compare with the national report.

The data collected through the KOOS and registration forms are sufficient for routine information needs regarding descriptive statistics and annual reporting. Nevertheless there will be research questions that will require further information and the need of specialized study designs to supplement the existing information available from the NKLR.

Data protection, patient identification and ethics

Due to the anonymity the NAR has promised their contributing orthopaedic surgeons, the NKLR has decided to follow the same line of policy in this matter. Therefore the quality control of surgical procedures and devices will be controlled by the registry, while the quality of the orthopaedic surgeons must be monitored locally in the hospital. The surgeon signs the form, but the surgeon's identity is not recorded, and thus cannot be traced in the registry. This is expected to ensure that results at hospital level are treated confidentially.

The patients are identified by their unique social security number (including date of birth), which is assigned to all Norwegian residents. The social security number is used to link the KOOS and registration forms, and to update the registry annually with data about

knee arthroplasties from NAR, and death and emigration data before extracting data files for analysis. The NKLR has been approved by the Data Inspectorate as an expansion of the NAR concession.

Since the establishing of the registry, it has been fully financed through the OSTRC. It is expected that with time the NKLR will receive government grants. To keep it's neutrality in respect of research questions and towards the orthopaedic community, it is important to the NKLR that it is continued without commercial sponsorship.

Staff and budget

The NKLR employs a secretary (50% position), a computer engineer (50%), and an orthopaedic surgeon (20%) as the administrative head of the NKLR. In addition, each hospital provides secretarial assistance amounting to approximately 10% of a full position. Due to the extensive collaboration with NAR the NKLR also has access to statisticians experienced in conducting registry studies. The total operating budget for 2009 for the central NKLR office is 704,100 NOK (approx. 79,000 €). This cost does not include salary for additional staff involved in various research projects based on the NKLR. It is expected that the basic operating costs will increase somewhat as the cohort and number of follow-ups increase year by year.

Scandinavian cooperation

Corresponding registries to the NKLR were started in Sweden and Denmark in January and July 2005, respectively. Their objectives, end points and minimal set of necessary data are almost identical to the NKLR. Main differences are that both the Swedish and Danish registries use web-based registration of data. The registries are organized and financed differently. In Norway and Denmark they are financed by the public health care system, whereas in Sweden one major private clinic provides financing. The majority of hospitals and clinics are reporting to all three registries. This will generate an expected annual average of 6600 patients. This pooled number of patients will within few years enable us to generate important data on the clinical performance of different surgical techniques, poor performing implants and epidemiologic aspects of knee ligament reconstructions.

Aims of this thesis

1. Establish epidemiologically data on ACL injuries before reconstruction, both descriptive and subjective outcome scores.
2. Demonstrate that a national population-based knee ligament registry can be developed, implemented, and maintained in Norway.
3. Establish a registry with sufficient compliance from both surgeons and patients.
4. Demonstrate that the NKLR will work as a warning against aggregation of inferior results.
5. Demonstrate that clinical useful tools can be directly developed from the registry.
6. Provide reliable KOOS values both pre-operative and post-operative.
7. Compare the Scandinavian registries in respect of epidemiology.
8. Compare the NKLR with the MOON registry to demonstrate cross-cultural differences and similarities.

Subjects, Materials and Methods

All patients included in papers I-IV are extracted from the cumulative Norwegian NKLR-cohort. In addition patient data were extracted patients from the Swedish, Danish and MOON cohorts for comparative analysis in papers III and IV.

In **paper I** the process of establishing the NKLR is outlined. Details considering this process are described in the Introduction part 2. Arguments and benefits of establishing such a registry are described. Descriptive statistics as of May 24, 2006 were described, and the minimum number of incidents needed to be reported to the NKLR – to detect inferior results and failures – was calculated.

In **paper II** all patients registered in the NKLR with primary ACL reconstruction surgery in Norway between June 7, 2004, and December 31, 2006 was reviewed. Details about age at time of surgery, sex, date of injury and date of surgery, location of any associated meniscal tears, and location and grading (ICRS) of any associated cartilage lesions were obtained. Patients were divided into 3 different age groups according to age at time of surgery: children, 16 years and younger; young adults, 17 to 40 years; and older adults, 41 years and older.

Because of logistic and diagnostic issues, patients not receiving surgical treatment for their ACL injuries are currently not included in the NKLR cohort. Thus, no control group was included in this study.

In **paper III** the Scandinavian (Denmark, Norway and Sweden) ACL registries with their main function, similarities and preliminary baseline results as of December 31, 2007 are described. The registries were established in 2004 (Norway) and 2005 (Denmark and Sweden). In Denmark all hospitals and clinics are legally bound to report to an approved national database, while the Norwegian and Swedish registries are based on surgeons voluntarily reporting. Reporting to the Danish and Swedish registries is organized through a secured internet portal, while the Norwegian registry relies on a paper-based reporting system.

In Denmark 90% of the orthopaedic departments have been contributing to the registry with an average compliance of 85% of the performed primary ACLR. In Norway all hospitals performing ACL surgeries have contributed with a total compliance of 97%. In Sweden some of the smaller hospitals with small volumes of ACL surgery have not been included in the registry, yet more than 71% of the hospitals have contributed to the registry. Follow-up with KOOS are carried out by all three registries.

Data regarding common and comparable variables (activities causing injury; age at injury and surgery; choice of graft; duration of surgery; frequency of cartilage and meniscal injuries, meniscal resections, and cartilage treatments; number of reconstructions and hospitals; graft fixation devices; outpatient surgery, pre operative and post operative KOOS; prophylactic antibiotics and anticoagulation; sex; and time to surgery) in relation to primary ACL reconstructions were extracted.

In **paper IV** the MOON cohort, established in 2002, and the NKLR are compared to identify similarities and differences in patient demographics (age and sex), activity associated with injury, time from injury to reconstruction, preoperative KOOS, meniscal and articular cartilage findings and treatments at reconstruction, and graft choice for

reconstruction regarding primary isolated ACLR. These data were compiled from two different years of MOON data (between January 1 and December 31, 2002; and between June 1, 2007 and May 31, 2008), and from three and one half years of NKLR data between June 7, 2004, and December 31, 2007. Approximately 500 primary ACLR are included in the MOON cohort annually.

We hypothesize that there are statistically and clinically relevant differences between the cohorts as well as important similarities that should be noted by surgeons attempting to extrapolate results from such databases to their own patients.

Statistical methods

In **paper I** we calculated proportion, mean and median values, range and standard deviation to describe data. The incidences were calculated as the annual number of primary ACLR in the different age groups and divided by the total number of Norwegian citizens, in the respective age groups, at the end of 2005. Preoperative KOOS for all patients were analyzed as groups.

In **paper II** logistic regression analyses (Cox 1972) were used to estimate the relationship between time from injury until primary reconstructive ACL surgery and the risk of meniscal tears or cartilage lesions. First, unadjusted analyses were performed to identify potential confounders. The relationships between time from injury until surgery and risk factors and between potential confounders and the risk of cartilage lesions or meniscal tears were calculated. Risk factors with a significant relationship (using $P < 0.20$) with time from injury until surgery and potential confounders with a significant relationship (using $P < 0.20$) to either cartilage lesion or meniscal tear prevalence were used as adjustment factors for potential confounding in the adjusted logistic regression models. The factors identified were age, sex, previous knee joint surgery (i.e. surgery to MCL, LCL, PLC, cartilage, medial meniscus, lateral meniscus, or other specified structure), current knee ligament injury (i.e. LCL, MCL, and/or PLC), meniscal tears, and cartilage lesions. The analyses were stratified by age groups and adjusted for time to surgery, sex, age (as a continuous variable), previous knee joint surgery, current knee ligament injury, and the presence of cartilage lesions or meniscal tears at the time of surgery.

Unadjusted analysis was performed to estimate the mean difference in months from injury until surgery between risk factors and confounding factors. P values less than 0.05 were considered to be statistically significant. Odds ratios are presented with 95% CIs.

In **paper III** we calculated proportion, median value and range to describe data. The incidences were calculated as the annual number of primary ACLR, during the registration period, in the different age groups and divided by the total number of each country's citizens, in the respective age groups. Preoperative KOOS for all patients were analyzed as groups.

In **Paper IV** Pearson's chi-square test was utilized to compare the proportion of men and women and the incidence of meniscal pathology in each cohort. Nonparametric methods (Mann-Whitney U test) were utilized to compare patient age and time from injury to reconstruction between the two groups as the data did not fit a normal distribution. A score in each of the five KOOS subscales was calculated for each patient utilizing the KOOS scoring sheet as published online. Mean and standard deviations for each subscale

were calculated for all patients for whom data was available in the respective databases and compared using a t-test as the data fit a normal distribution.

For all statistical analyses in papers I-IV the statistical software package SPSS version 13.0 and 15.0 (SPSS Inc 2001, Chicago, Illinois, US) was used.

Results and Discussions

This part of the thesis summarizes the results and discussion in each included paper. Details are found in each separate paper (I-IV).

Results

Paper I found that the annual population incidence of primary ACLR was 34 per 100 000 citizens, while the incidence in the 16 to 39 years age group was 85 per 100 000 citizens, both higher than previously published figures. Since we do not know the ratio of surgically treated versus conservatively treated cases, the population incidence of ACL injuries is not known.

Less than two years after the NKLR had started the compliance rate in relation to the hospital protocols and the NPR were 97% and 98%, respectively. A compliance of more than 95% is in line with what can be expected from a well established Norwegian hip or knee arthroplasty registry.

Furthermore, descriptive statistics are presented for the primary ACLR, primary PCL reconstructions, combined primary ACL and PCL reconstructions, and revision ACL and/or PCL reconstructions. These data are presented as baseline data after two years of running to demonstrate the epidemiology of cruciate ligament surgery in Norway.

The findings in **paper II** are based on 3475 primary ACLR with known date of injury and without additional PCL injury or surgery, previous or current. The median time from injury to surgery was 7 months, median age at time of surgery was 27 years, and 57% of the patients were males.

Children did not experience a significant increase in odds for either cartilage or meniscal tears with increase in time from injury. Among the adults there were significantly increased odds for cartilage lesions for each month that elapsed from the injury date until the surgery date, for the presence of previous surgery to knee ligaments, and for the presence of a meniscal tear. But an additional current knee ligament injury or increasing age of the patient only increased the odds for cartilage lesions among the young adults.

Presence of cartilage lesions increased the odds for meniscal tears among the adults. While being female or the presence of previous surgery to knee ligaments decreased the odds for meniscal tears. Increasing age among the young adults also decreased the odds for meniscal tears. But by each month that elapsed from the injury date until the surgery date the odds for a meniscal tear increased in the young adult group.

The findings in **paper III** were based on 4972 primary ACLR registered in Denmark, 5329 in Norway, and 7331 in Sweden. In Norway 57% were males, in Sweden 58%, and in Denmark 60%. Most often soccer was the cause of injury (Norway 40%; Sweden41 %; Denmark 50%). Of the Danish patients 39% had simultaneous meniscal injuries and 17% had cartilage injuries. In the Norwegian patients the corresponding figures were 55% and 27%, and in Sweden 35% and 27%. The median age of the patients at the time of injury varied between 23 (Sweden) and 27 years (Denmark), while the median age at the time of surgery varied between 25 (Sweden) and 30 years (Denmark). The median time, in months from injury to surgery varied between 7 (Norway) and 10 (Sweden).

The annual incidence of primary ACLR varied between 32 per 100 000 citizens in Sweden, and 38/100 000 in Denmark. The real population at risk had an incidence of 85/100 000 in Norway (16-39 year age group), 91/100 000 in Denmark (15-39 year age group), and 71/100 000 in Sweden (20-39 year age group). Detailed annual incidence rates for both genders and various age groups are provided in paper III.

In **paper IV** 713 patients from the MOON cohort were compared with 4928 patients from the NKLR. A higher percentage of males (NKLR 57%, MOON 52%; $p < 0.01$) and increased patient age (NKLR 27 years, MOON 23 years; $p < 0.001$) were noted in the NKLR population. ACL injuries were associated with a sport in 89% of those for whom an injury mechanism was known in the MOON cohort, and 87% in the NKLR. The most common sports associated with injury in the MOON cohort were basketball (20%), soccer (17%), and American football (14%); while soccer (42%), handball (16%), and downhill skiing (10%) were most common in the NKLR. Median time to reconstruction was 2.4 months in the MOON cohort and 7.9 months in the NKLR cohort ($p < 0.001$). Statistically significant differences between the two databases were noted in each KOOS subscale except QOL; however, only the difference in the "other symptoms" subscale was clinically significant. Both meniscal tears (MOON 65%, NKLR 48%; $p < 0.001$) and articular cartilage defects (MOON 46%, NKLR 26%; $p < 0.001$) were more common in the MOON cohort. Hamstring autografts (MOON 44%, NKLR 63%) and patellar tendon autografts (MOON 42%, NKLR 37%) were commonly utilized in both cohorts. Allografts were much more frequently utilized in the MOON cohort (MOON 13%, NKLR 0.04%; $p < 0.001$).

General discussion

RCTs versus observational studies

In December 2005 three editorials (Carr 2005, Horan 2005, Tovey and Bognolo 2005) were published on the subject of evidence in orthopaedic surgery. They all claimed that RCTs are far from enough to serve the well being of orthopaedic patients and the orthopaedic community with sufficient and enough evidence to pursue a qualitatively and optimally state of the art in surgery. Horan (2005) states that carrying out high quality RCTs in (orthopaedic) surgery may turn out to be impossible due to ethical considerations, individual adherence to protocols, sufficient power and the interpersonal variations in skills and techniques. Pocock and Elbourne (2000) put unwillingness as an addendum to the list of troublesome considerations. While Carr (2005) claims that "without sponsorship and financial support surgical trials are simply impractical. An alternative to trial based research is a register, but these have proved difficult to establish even for high profile treatments such as hip replacement." A claim supported by the lack of success of the National Joint Register in the UK. There is sufficient evidence that other national Arthroplasty registries have proven differently (Havelin et al 1995a, Havelin et al 1995b, Herberts and Malchau 1997, Malchau et al 2002).

It is important to emphasize the fact that the results of a well designed observational study (e.g. a cohort study) are not qualitatively different from a RCT on the same topic in respect of treatment effects (Benson and Hartz 2000, Concato et al 2000). "Our results suggest that observational studies usually do provide valid information. They could be used to exploit the many recently developed, clinically rich databases. Only with a greater willingness to analyze these databases is it possible to achieve a realistic understanding of how observational studies can best be used (Benson and Hartz 2000)." And finally observational studies are used primarily to identify risk factors, prognostic indicators and in situations in where RCTs are impossible or unethical (Naylor and Guyatt 1996).

Jahn and Razum (2001) have pointed out that observational studies test real life when treatment depends on the individual performance of a health worker (i.e. an orthopaedic surgeon in this setting). Coomber and Perry (2001) suggested that an experiment (a trial) is fundamentally different from an observation, in that an experiment is designed to test a hypothesis. Observation is to view the 'real world', and the latter should follow the former to test the experiment's applicability – the two processes are complementary. These authors also emphasize that most observational studies are poorly supported (Coomber and Perry 2001). Jahn and Razum (2001) do, in agreement with the former authors, conclude their argument by stating: "From a client's perspective, what matters is the health benefit conferred by an intervention done in clinical routine, and not its efficacy in a RCT. Therefore, observational studies are indispensable."

Finally it is suggested by Pocock and Elbourne (2000) that "observational databases can be useful adjuncts to RCTs, to see whether efficacy under controlled conditions in specialist centers translates into effective treatment in routine practice." And he adds that observational studies may turn out useful in generating ideas for new controlled trials.

In general, it may be argued that RCTs are better than cohort studies to assess the outcome of cruciate ligament surgery. Although RCTs are preferable to address specific research questions, such as comparing one surgical procedure to another, they are difficult to organize, time-consuming, and costly. Therefore, it is often not possible or even justified to conduct a RCT to address anything but major differences in procedures or devices. One example may be minor changes in screw design or materials. A national registry can be used to assess results with minimal additional work or cost. However, it should be noted that in a nonrandomized cohort study, confounding factors must be adjusted for, either by selection of homogeneous subgroups or by use of a multiple regression model when analyzing the results (Havelin et al 2000).

An important addendum regarding registries versus focused longitudinal studies. The essence is that the latter studies are not likely to provide information that can readily be generalized. This is due to the fact that studies from these kinds of centers usually omit the orthopaedic surgeons' learning curve that may affect early results. Also, these orthopaedic surgeons tend to be more experienced and interested in this type of surgery than the general orthopaedic surgeon and therefore their results may prove better.

Why establish a registry

It is important to remember that a medical registry – such as the NKLR – is the only systematic assessment of quality regarding treatment protocols, devices and outcomes for patients receiving cruciate ligament surgery in Norway.

In October 2001 Maloney (2001) demonstrated the rationale for the establishment of a national joint replacement registry in the United States. Although that article dealt with joint replacement, most of it is also true for cruciate ligament surgery. The following paragraph is based on his reasoning. All new fixation and other devices used in cruciate ligament surgery are expected to be at least equivalent to the existing devices. And there are – regardless the amount of testing prior to release of new devices – only in our patients that all the known and unknown variables that possibly can affect the outcome will come into play. As a result premature failures and undesirable outcomes will occur. Consequently, one must consider if the magnitude of premature failures and undesirable outcomes are serious enough to warrant the expenditure of resources. If you consider the incidence of ACL injuries, surgery and the inevitably development of OA, the answer is yes. Therefore the next question to address is what is the optimal way to disseminate information in the orthopaedic community in order to have a timely and positive effect on the problem? Three potential basic methodologies for studying outcomes of performance are presented as alternatives: RCTs, meta analyses and retrospective case series. RCTs are rejected amongst others due to impracticalities. Meta analyses are rejected since there is not enough RCTs examining the relative efficacy of different cruciate ligament surgery designs carried out in large numbers. Retrospective case series are rejected due to limitations in the design: these studies often represent the experience of a single surgeon or center and they are often recognized as sub specialized experts, and do not reflect what is going on in the general orthopaedic community, where cruciate ligament surgeries are performed in large measures. The most important limitation is perhaps the fact that the time delay that is implicit in the design does make it unattractive as an early warning system for procedures with problems. Since these alternatives fail to answer our question,

we are left with the question of how it can be done better. The most likely answer is a national registry.

In addition the NKLR consider the four following aspects as important when establishing a national medical registry. Primarily, all data should be collected for research use. The average number of patients treated with cruciate ligament surgeries in the different participating hospitals is small, so pooling of data will in the future produce a larger resource for research. It will also decrease potential problems with bias. Therefore, information and research provided through the NKLR is a method for assessing the quality and results of cruciate ligament surgery in Norway (Sachs and Synnerman 1999), and is considered an important tool to monitor and improve the quality of treatment (Havelin 1999).

Secondly there are audit purposes; the recording of consecutive cases of the different surgical procedures helps in preparing patients with similar injuries and allows comparison for audit purposes, in order to asses the effectiveness and safety of treatment and set standards – and eventually national guidelines – in the future.

Thirdly it is to study whether centralization of certain procedures yields improved overall results. The NKLR's database contains information on parameters such as volume and treatment outcomes, and may provide facts in the discussion about centralization – and thus hospital volumes – of cruciate ligament surgeries (Katz et al 2004). Today there is a need for additional studies in the various orthopaedic subspecialties to establish definitive conclusions in respect of hospital or surgeon volume and treatment outcomes (Shervin et al 2007). However, it is also important to give the hospitals with poorer results time to improve by following the examples of better practices.

And finally, a reason introduced by the health authorities is that a registry may be able to identify hospitals with general poor surgical outcomes and terminate cruciate ligament surgery in these hospitals or clinics; a concern that may cause serious compliance difficulties among the surgeons. Experiences gained from existing registries (e.g. NAR) indicate that the health authorities intend for registries to serve as tools for continuous surveillance and quality control rather than as means of regulating the surgeons' practice. In Norway, both NAR and the NKLR are owned by NOA, and only summary results are released to the health authorities. The NKLR set up makes it impossible to track the individual surgeon, but the hospital may be identified.

Swiontkowski (2003) once wrote that "in order to continue to serve our patients in the best way possible, we need to understand the results of our treatment so that, as new treatments and approaches are developed, we may continually offer our patients the best treatment options possible. This requires a detailed knowledge of the end results or outcomes of our care. It is our responsibility and is an important component of our efforts to maintain our competence in caring for patients." These words may stand as the NKLR's superior conscience as we start to serve to orthopaedic community.

Purposes of a registry

Patient registries are established to improve the standards of health care. Specifically, they are meant to serve three purposes: to improve treatment outcomes through feedback to the hospitals and surgeons, to detect procedures and devices that result in premature

failure, and to identify prognostic factors associated with good and poor outcomes. To serve these purposes, the accuracy of the outcome measures used is critical. The joint registries, including NAR, only use revision surgery as an end point. Thus, patients may have a poor result (e.g. knee laxity, knee instability, knee pain) without this being registered. In contrast, in addition to revision surgery, NKLR also includes routine follow-ups with patient-reported KOOS as the primary end point. KOOS are collected preoperatively from the patients, as well as after 2, 5 and 10 years postoperatively. The intention is to detect inferior results and early failures, regardless of whether patients with a failed graft decide to go through revision surgery or not. Also, at a later stage, data from NKLR can be combined with data from NAR on knee arthroplasties, thus using surgically verified severe OA as an additional end point.

To serve its first purpose, to improve treatment outcomes through continuous feedback to the participating hospitals, hospitals are each year provided with results on their own patients and national data. This is based on the idea that hospitals able to compare their outcomes with national averages will improve by following the better examples. An annual report is sent to all the members of the NOA, to all hospitals performing cruciate ligament surgery, and to the health authorities, and also published on the joint website of NAR and NKLR (http://www.haukeland.no/nrl). The NKLR depends on participation from all orthopaedic surgeons performing cruciate ligament surgery, including those normally not involved in research. Feedback is therefore also important to maintain motivation and interest in the registry and we believe the reporting procedure explains the high compliance with the registry. Based on our previous experience with NAR, it may be expected that compliance will remain high.

The second purpose, to detect procedures and devices that result in premature failure, can be achieved based on revision surgery or, if a revision has not been performed, deterioration of the KOOS (Paradowski et al 2006). The following example illustrates this point. A score of at least 60 points in the QOL subscale may be expected with a successful outcome after surgery (Roos et al 1998a). Age- and sex-specific general population reference values are also available for all 5 KOOS subscales (Paradowski et al 2006). A change in the KOOS of 10 points can be considered a clinically significant difference – as an improvement after surgery or deterioration after graft failure (Paradowski et al 2006). Thus, the number of patients needed to detect failure in a cohort study may be calculated. Assuming a more conservative estimate, that a difference of 20 points is sufficient to predict an inferior device or procedure, as few as 14 failures are needed, using standard statistical values. These estimates also apply if the purpose is to discover prognostic factors that are associated with good or poor outcomes. For example, there are many patients with large cartilage lesions (>2 cm^2) and lesions graded 3 or 4 that are of special interest as their treatment outcome may be less predictable. Thus, because it may be estimated that the registry will include 2-year outcome data on approximately 8000 patients with isolated ACLR after seven years of operation, it seems reasonable to assume that the registry will be able to provide relevant data on inadequate procedures and devices. However, less common procedures and devices will be difficult to assess, and it should be noted that the frequency of devices in use varies considerably (paper I). Also, isolated PCL reconstructions and combined ACL/PCL reconstructions are much less frequent than isolated ACLR, and for these procedures it will be difficult to

study subgroups, even with a national registry (paper I). However, this may be achieved when the registries of Sweden, Denmark, and Norway are combined.

Norway is the first country in the world to have a national population based registry of cruciate ligament surgeries. The costs of establishing and maintaining (budget on 704,100 NOK in 2009) such a registry as the NKLR, is fairly small in relation to the community costs (conservatively estimated to 616.525 millions NOK) of untreated cruciate ligament injuries, and these costs should be regarded as an investment.

Limitations and Strengths of the NKLR

A general limitation due to ACL surgery, and not specific to the NKLR, is the influence psychological factors might have on the patients outcomes following ACLR (Brand and Nyland 2009). Langford et al (2009) found that only 51% had returned to full competition 12 months following ACLR. There were no clinical differences between those who returned and those who did not return to competition. They concluded that during rehabilitation there are significant psychological differences regarding sport resumption between athletes who do, and do not, resume competitive sport 12 months following ACLR. These differences occur already at 6 months postoperatively and highlight the importance of addressing all aspects of an athlete's recovery in order to help facilitate the timely return of athletes to competitive sport. This psychological response regarding sport resumption during rehabilitation may be identified using the ACL-RSI (Webster et al 2008). The magnitude of this problem is not sufficiently mapped yet. This might bias our findings and for now we have no way to counteract this problem.

One might argue that it is inadequate to launch a registry today and make it paper-based, not web-based. Experiences from NAR reveal a high compliance rate (i.e. a compliance rate of nearly 100% that has not declined during 20 years of operation) with the paper-based data collection, and there is an understandable reluctance in changing a well established practice. A transition to web-based registration will be executed simultaneously for the two registries. Secondly, there is sound and safe procedure to introduce one new element (the registration form) for the orthopaedic community and not two (addition of web-based registration) elements at once. Thirdly, the degree of access to the external internet in the local hospitals still vary considerably due to data security reasons, and therefore there would imply unintended extra work for the orthopaedic surgeon to fill in a web-based registration form. This also includes the problem of not having a uniform, nationwide standard on surgical and patients' hospital records, and thus uniform drafts from these records would either imply extra work for the hospitals or the same amount of overload to NKLR's secretariat. This challenge will be taken into account when a prospective web-based solution is launched. The same argument is also valid for the amount of administration and data registration that the NKLR's secretariat would be subjected to. The paper-based NKLR have also revealed better compliance than the web-based Swedish and Danish registries, at least for the first few years of running (paper III).

It is important to emphasize what the NKLR will not be able to demonstrate. There is no radiographical follow-up of the ACLR patients. Consequently, data regarding the development of radiographically verified OA will not be obtainable. The choice of not doing radiographic follow-ups is due to both financial restraints and the intention to not

put additional demands on the hospitals that are beyond their own follow-up routines. More advanced investigations (e.g. gait analysis and muscle strength) are also omitted, due to the same arguments.

An important limitation in the NKLR is bias due to limitation in follow-ups. We know that baseline compliance is high both in respect to registration forms and KOOS forms. Every year the preoperative KOOS form has been completed by more than 80% of the patients, recognized as a very good compliance rate in an epidemiologic setting. But the two year follow-up compliance rate is down to 60%, prior to any reminders to the patients. This raises the question about how much work should NKLR put into attempts to increase the response rate? Is a 70% response rate instead of 50% sufficiently more beneficial? Is it cost effective?

Only in recent years have there been conducted well designed studies to document the consequences of lower response rates, and these studies challenge the presumption that a lower response rate means lower survey accuracy. Curtin et al (2000) tested the effect of lower response rates on estimates of the Index of Consumer Sentiment (i.e. degree of optimism that consumers feel about the overall state of the economy and their personal financial situation). They assessed the impact of excluding respondents who initially refused to cooperate (reduction in response rate of 5 to 10 percentage points), respondents who required more than five calls to complete the interview (reduction of approximately 25 percentage points), and those who required more than two calls (reduction of approximately 50 percentage points). They found no effect of excluding these respondent groups on estimates of monthly samples, and only minor effect on the yearly estimates. Experimental comparisons have also revealed few significant differences between estimates from surveys with low response rates and short field periods and surveys with high response rates and long field periods, some studies even show that the least bias comes from surveys with less than optimal response rates (Visser et al 1996, Holbrook et al 2005, Keeter et al 2006). Thus it seems that a low response rate does not guarantee lower survey accuracy and instead simply indicates a potential risk of lower accuracy. Therefore response rates should be treated with skepticism, and instead one should pay attention to other indicators of quality, such as insignificant levels of bias, low levels of missing data, and conformity with other research findings (American Association for Public Opinion Research 2009). Nevertheless, it is essential to distinguish between surveys that are meant to be generalized to a representative national average and true national data.

In Denmark a notification on improvement of nationwide and regional clinical quality database made data registration to the National clinical databases approved by the National Board of Health compulsory for all public and private clinics. Furthermore, data registration in both the Swedish and Danish databases can take place without the patients' consent. This might be an important condition to maintain a high compliance rate, but yet enough time to evaluate this approach is still to come. The patients' unique social security number makes it easy to reach every patient, and thus increase the response rate in the follow-ups. Even though compliance is of importance, so is the completeness of the registered data. Completeness – in respect to the orthopaedic surgeons reporting the same information to the NKLR as they do to the hospital records – has not been investigated.

There still are issues where the NKLR has no solution. Due to logistic and diagnostic issues, patients not receiving surgical treatment for their ACL injury are currently not included in the registry. Thus, no data on the outcome of non-operatively treated ACL injuries are obtained. Nevertheless, some studies have shown that most cruciate ligament injured patients will see medical care and thus could be entered into the registry (Grontvedt et al 1999). To be able to retrieve a sufficiently large material on a national scale, in respect of the conservatively treated ACL injuries, the NKLR should turn to the Norwegian research center for Active Rehabilitation to conduct a prospective joined multi center cohort study. The timing of such a study is essential since it will occupy considerable resources, both in terms of manpower and finances.

Another limitation in these registries is the use of revision as a primary end point. This is suboptimal since an unknown number of patients accept to live with an inferior clinical outcome to avoid more surgery. However, if they undergo surgery for debridement or arthroscopic surgery for other indications, they will be detected in the registry. Knee arthroplasty has limitations as an endpoint because it can take several decades before a patient with a poorly functioning knee is accepted as a knee arthroplasty candidate. Neither do all patients with ACL insufficiencies develop OA to a degree where total knee arthroplasty is indicated (Lohmander et al 2007, Øiestad et al 2009).

The registration of potential risk factors other than type of surgical procedure may be subject to selection bias. The data items recorded are a minimal set suited for a paper-based or web-based reporting system, not to exceed one page. As such there has to be a careful, ongoing selection of what is expected to be the most important risk factors. Thus, there is no way of knowing the influence of the omitted variables. Finally there might be limitations due to differences between Scandinavia and other countries in respect of indications for surgery and patient success criteria.

Prospective national registries have several advantages. Inclusion of cases from an entire nation generates a high volume of data. This in turn, will lead to the possibilities of drawing early decisive conclusions. When the inclusion of an entire nation continues over several years, there will be an additional benefit of large variation in the population, which one will be able to study through follow-ups. Another advantage is due to the nature of cohort studies, an ongoing accumulation of short term and long term follow-up data. Finally there is the advantage of monitoring development, implementation and evolution of new – and old – techniques, implants, prophylactic medications and so forth. Although RCTs are the gold standard in research methods and are immensely valuable for detailed testing, they are insufficient when assessing techniques. A RCT aiming to demonstrate a 5 % difference in revision rates after ACL surgery would need nearly 500 patients in each group, far more than usually included in a typical RCT in knee ligament surgery. The most important benefit of the NKLR is probably that one is allowed to study several end points and exposures at the same time. For instance one may describe all the different health consequences attached to one exposing factor, or describe several different exposures at the same time and attach them to one outcome. By including a high number of participants the results will be statistically reliable, also when studying rare cases.

Hopefully the NKLR can contribute to monitor if ACL injury prevention efforts, amongst others initiated and developed by researchers at the OSTRC, is effective also after the intervention ceases.

Subjective end points

The choice of the KOOS form over other alternatives took a number of elements into consideration: The form should be patient-based to allow for non-biased outcome data. The form should be self-explanatory, and time required to complete the form should be kept to a maximum of 10 minutes to ensure good compliance at follow-ups. Finally, the form had to be validated for cruciate ligament surgery. These requirements left us with two choices (Johnson and Smith 2001): KOOS (Roos et al 1998a) or IKDC 2000 (Irrgang et al 2001). We chose the KOOS form because, in our opinion, it is more user-friendly from a patient's perspective than the IKDC 2000. However, it remains to be seen how well patients will comply with the long-term follow-up procedures.

Like most questionnaires, the KOOS has been substantially validated using analyses based on classical test theory (e.g. face validity, construct validity, test-retest reliability, and responsiveness) (DiFabio and Boissonnault 1998, Roos et al 1998a, Roos et al 1998b, Roos and Lohmander 2003, Roos and Toksvig-Larsen 2003, Comins et al 2008). As such, it is valid and reliable for short- and long-term follow-up studies of knee injury and OA in patients aged 14 to 78 years, with both high and low physical activity levels (Roos et al 1998a, Roos et al 1998b, Roos and Lohmander 2003). In addition the KOOS were considered reliable and responsive for assessment of knee complaints in a comparative review of knee specific outcome measures (Garratt et al 2004). Even though this might be considered as sufficient scientific testing of a questionnaire, others (Wright and Mok 2000) claim that classical test theory is not sufficient to establish unidimensionality (i.e. a scale's capacity to measure the specific attribute or dimension of interest, which in practical terms entails the summation of raw item scores into a single overall score (Comins et al 2008)). According to Tennant et al (2004) that it is increasingly recognized that scores generated from questionnaire subscales are more valid if analyses based on item response theory (e.g. Rasch analysis) have been conducted. Analyses using the Rasch model of item response theory have previously been used to assess the validity of WOMAC (Ryser et al 1999, Wolfe and Kong 1999). The study by Comins and coworkers (2008) is the first to validate any instrument used for subjective assessment of ACL-deficient persons by using Rasch analysis. This study revealed that only the two subscales that were added to the WOMAC (i.e. function in Sport and Recreation, and knee related QOL) exhibited unidimensionality. Thus, the three sub-domains in KOOS extracted from WOMAC may be appropriate for patients with OA, but not for ACL-deficient persons that have not yet developed degenerative disease of the knee (Comins et al 2008). To the best of my knowledge, KOOS is still the only instrument used for subjective assessment of ACL-deficient persons validated by using Rasch analysis.

The idea behind doing routine follow-ups at two, five and ten years, in addition to the pre-operative baseline scoring, were diverse. Primarily we wanted to do a screening of all the patients with the intention to detect inferior results and early failures which is known to happen within two years. Secondly we wanted to perform a crude screening of the patient pool to check for soft end points (e.g. patients with a failed graft that have decided

to not go through revision surgery or cases that have failed to register subsequent knee surgery procedures in the NKLR). Thirdly we wanted to know the long term subjective outcomes of the knee joint after cruciate ligament surgery. Finally we wanted to make the registration continuous. The relationship between compliance and quality has already been discussed. But in relation to the soft end points it is essential to distinguish between research on groups and on individuals. There is impossible to keep track of the individualized outcome and development over time without feedback. Likewise, when it comes to rare cases or small population subgroups a high compliance is preferable. Otherwise the detection of inferior results would be delayed or even possibly ruined.

The complete assessment of the benefits of an intervention must include evidence of the effect on the patient's health status and QOL, end points that are of genuine importance to patients (Garrat 2009). The NKLR has routine follow-ups with the KOOS at two, five and ten years postoperatively. As such the disease specific patient status is sufficiently assessed. In addition there should be done an evaluation of the patients' (general) health-related quality of life and health status. This is probably best done through adopting the Swedish registry's procedure on using the EQ-5D (Brooks et al 1991) in addition to the KOOS. EQ-5D is available in a validated Norwegian translation (Rabin and de Charro 2001).

Specific discussion

Paper I demonstrates that a national population-based cruciate ligament registry can be developed, implemented, and maintained in Norway. Such a registry provides data on more than 95% of all patients undergoing primary ACLR. It may be expected that the NKLR can enable us to identify inadequate procedures and devices, as well as prognostic factors associated with good and poor outcomes, at least for the most frequent categories.

There is expected that the registry each year (based on data from 2008) will enroll approximately 1600 primary ACLR cases, 15 primary PCL reconstruction cases, and 30 cases of primary reconstruction of both cruciate ligaments.

The detection of procedures and devices that result in premature failure can be achieved based on revision surgery or, if a revision has not been performed, deterioration of the KOOS. Based on conservative estimates and using standard statistical values, as few as 14 failures are needed, in a given subgroup, to detect failure in a cohort study. This estimate also applies if the purpose is to discover prognostic factors that are associated with good or poor outcomes. Less common procedures and devices will be more difficult to assess. The same applies for the substantially less frequent isolated PCL reconstructions and combined ACL/PCL reconstructions. For these procedures it will be difficult to study subgroups, even with a national registry. However, this may be achieved when the registries of Sweden, Denmark, and Norway are combined.

The main strengths in **paper II** are the large number of patients included, and that they originated from a national and general population of ACL-injured patients. The main weakness is that all details regarding the patients' cartilage and menisci findings and descriptions are solely based on the individual orthopaedic surgeon's arthroscopic examination and subsequent reporting to the NKLR. On the other hand, the conclusions

relate to if meniscal tears and cartilage lesions exist or not, something most orthopaedic surgeons would agree on.

Patients who had asymptomatic cartilage or meniscal injury before their ACL injuries represent a potential source of bias. One cannot be entirely sure that the cartilage and meniscal tears reported to the NKLR had been sustained at or after the index ligament injury. Another potential limitation is that patients who expect instability to be a problem or cannot afford instability problems (e.g., manual laborers, professional athletes, those who perform pivoting leisure-time activities) are more likely to undergo surgery early in contrast to patients who receive surgery after having experienced at least one episode of instability or giving way of the knee. Also older patients are more likely to try non operative treatment before undergoing surgery. On the other hand the chance of having surgery increases if you sustain further injuries to the knee as time goes by. The consequence is that we might overestimate the importance of time as a risk factor for developing degenerative lesions.

Patient's weight and activity level might also bias the results. Either one of these factors is considered to increase the incidence of cartilage lesions and/or meniscal tears. The former were included in the pre operatively and post operatively KOOS forms after the study period of paper II. The latter is still a limitation in the registration process. The Tegner Activity Scale (Tegner and Lysholm 1985, Briggs et al 2009) is currently being considered for inclusion in both pre-operative and post-operative KOOS forms.

Children neither experienced significant increase in odds for either cartilage nor meniscal tears with increase in time from injury. These data are considered indicating that the Norwegian approach (Moksnes et al 2008a), to delay ACLR until skeletal maturity, does not lead to increased incidence of meniscal tears and cartilage lesions. This leads to a long time period between injury and stabilizing surgery for children with an early ACL tear. The protocol for these children consists of activity modification and use of a brace when performing knee-demanding activities. Children with severe knee injuries still undergo early surgery.

An unexpected finding is that while ageing seems to increase the odds for cartilage lesions among the early adults, aging decreases the odds for meniscal tears. While the increase in cartilage lesions cannot be ascribed to the natural development of OA, the combination of these two findings do not coincide with the common belief that meniscal tears predispose the knee joint for cartilage lesions and the development of premature OA. It is more likely that the mechanics behind the ACL rupture also damaged the intra articular cartilage, but spared the menisci.

On the basis of the results on adults, early surgery may be recommended. Nevertheless, it must be emphasized that paper II only consider when surgery should be done in accordance with increased risk of developing cartilage lesions and meniscal tears. It does not consider if surgery should be done to reduce the development of post traumatic OA. A reasonable cutoff, tailored to the orthopaedic surgeon's individual recommendations on when to perform primary ACLR, can be calculated for each patient based on the data presented in paper II. Detailed examples on how this cutoff can be calculated are available in the appendix to paper II. Thus, providing individualized risk profiles for cartilage lesions and meniscal tears based on the logistic regression model.

Paper II concludes that the odds for a cartilage lesion in the adult knee increased by nearly 1% for each month that elapsed from the injury date until the surgery date, and the presence of cartilage lesions was associated with a nearly two-fold increase in the risk of having meniscal tears, and vice versa, independent of patient age. The data suggest that early surgery is associated with fewer meniscal tears and cartilage injuries.

Paper III found that a similar approach to the patients exist among the Scandinavian surgeons. Variations do however exist regarding choice of grafts (61% hamstring autografts in Norway and 86% in Sweden), implants, treatment of simultaneous meniscal and cartilage injuries, and use of prophylactic anticoagulation (17% in Denmark and 78% in Norway). This probably reflects cultural variations, while the proportion of ACL reconstructions performed as outpatient surgery (38% in Norway, 56% in Sweden and 79% in Denmark) probably reflects the variation in the Scandinavian structure of the health care systems.

In respect of choice of autografts and fixation, the implants used in more than 2/3 of the cases varied between one and three different implants in the different registries. This gives an overall total of four to six different implants when looking at various grafts and their different fixation sites. This variation in the Scandinavian countries might be due to personal preferences, skill of medical company sales team or local financial decisions, or a combination.

The only national clinically significant differences in KOOS were that the Danes score poorer on the KOOS symptom subscale, both pre-operatively and post-operatively. Furthermore, the Danish and Swedish baseline KOOS reveals an unsatisfactory compliance rate, both for unknown reasons. The baseline KOOS presented in paper III are the most comprehensive data set published to date, and should be regarded as the reference values for preoperative KOOS in ACL injured patients.

As already mentioned, the compulsory reporting to the Danish ACL registry, and the Danish and Swedish exemption from obtaining patients' consent might prove beneficial, given time. The Swedish hospitals and clinics with smaller volumes are not included in the registry. This is likely to bias the results regarding volume and outcomes, but not necessarily on an aggregated national level. Both Sweden and Denmark have poorer compliance in respect of registration forms and KOOS forms. There are only two major differences between these registries. Norway is the only registry that uses paper-based reporting, and the only that exclusively report national averages to the public. Sweden and Denmark both rely solely on web-based solutions and the reports also include data on individual or department specific levels. One might question if the extra gain in analyzing data on individual or department level is lost on behalf of compliance rates.

Paper III concludes that the Scandinavian national ACL registries will generate new data about ACLR. They will contribute important knowledge regarding ACL epidemiology. They will be the only source for data on performance of a wide range of different implants and techniques. They will influence the selection of methods for ACLR in Scandinavia and hopefully elsewhere.

In **paper IV** there were found that important differences exist between the MOON and NKLR populations related to patient demographics, activity leading to injury, time to reconstruction, presence and treatment of intra articular pathology, and graft selection.

However, similarities also exist, including the almost identical percentage of injuries due to sport as well as similarities in pre-operative KOOS.

A key question in the analysis and interpretation of outcomes from prospective databases is their applicability to geographically and culturally diverse populations. Attempts to generalize results from one specific population to another could lead to inaccurate conclusions unless the similarities and clinically relevant differences are known. Even though several differences exist there are limitations that must be considered before acting upon the findings in this paper.

The MOON patient group is not a complete cross section of patients with ACL tears in the United States, as the majority of ACL reconstructions in the country are performed by surgeons in private practice and MOON recruits their patients from a university population.

The NKLR is a national registry with reports from all patients in Norway undergoing ACL surgery, whereas the MOON cohort is recruited exclusively by surgeons at seven academic medical centers in the United States. Similarly, healthcare system differences may introduce biases into which patients present to surgeons for reconstruction, given that not all Americans have insurance and easy access to providers. The argument regarding the MOON cohort not being representative for the United States' ACLR patients is emphasized in the following comparison. According to the responders (57%) of a survey mailed to physician members of the American Orthopaedic Society for Sports Medicine in 2006, patellar tendon autograft was preferred most often (46%), followed by hamstring autograft (32%) and allograft (22%) (Duquin et al 2009). This is in contrast to the corresponding figures from the MOON cohort, which is 42%, 44% and 13%, respectively.

Finally, treatment algorithms for ACL injuries differ between the two countries, with non-operative management of ACL injuries attempted much more frequently in Norway (50% according to Granan et al 2004) than in the MOON cohort (5-10%).

Regarding the increased amount of associated intra articular injuries at the time of ACLR and the significantly lower median time to reconstructive surgery in the MOON cohort, drawing reliable conclusions is difficult. In 14% of the cases in the MOON database there is lacking information about the injury mechanism. Also, 35% of patients in the MOON database were unable to identify a specific injury date. These factors are likely to lead to an underestimation of median time to surgery, misinterpretation of the impact of time on development of intra articular injuries, and uncertain conclusions on which injuries, and the severity of them, may be anticipated based on injury-causing activity and injury mechanisms. Since the MOON cohort is not likely to be representative for the United States and the American health care system differs in essential ways from the Norwegian, we must expect to encounter problems with bias in this case as well.

Similar differences potentially exist between other databases from various locations around the world. Surgeons should investigate the patient and surgical characteristics of such databases when applying knowledge from these groups to their own patient populations.

Future perspectives

National cruciate ligament registries are an important and irreplaceable contribution to the scientific solution of the challenges ACL injuries represent. Important future perspectives have recently been outlined by international ACL authorities:

"The optimal treatment of patients who have a partial ACL tear, who are skeletally immature and have an ACL tear, or whose ACL graft has failed remains unclear; multicenter observational studies of such patients are ongoing. The risk of future OA associated with ACL tears and potential modifiers of this risk (including meniscus and articular cartilage injuries and their treatments) remain incompletely understood, and it remains unclear how to best minimize this risk. Further studies are needed to define appropriate non operative treatment of ACL tears, the optimal time to return to sports, and the influence of hormones on the risk of such injuries. The potential role of tissue engineering to enable successful repair of associated injuries (including avascular-zone meniscus tear and articular cartilage injuries) is unclear." Spindler and Wright (2008)

"Patient registries are established to improve the standard of health care and should be used in as many countries as possible. One vision is to have a common international registry for knee ligament surgery supported by, for example, ESSKA and ISAKOS. For countries that need a separate database for legal reasons, the software could be the same for all countries. In a very short time, a huge amount of data could be obtained, and fruitful international comparisons would be possible." (Engebretsen and Forssblad 2009)

Summary of thesis

1. Paper I provides reliable descriptive baseline data for the general ACL epidemiology, as well as subjective outcome scores. Further epidemiologically data are provided in paper II, and further subjective outcome scores are provided in paper III.
2. Paper I demonstrates that a national registry, such as NKLR, can be developed, implemented, and maintained in Norway at a reasonable cost.
3. Paper I demonstrates an excellent response rate from both surgeons (97%) and patients (>80%).
4. Paper I displays that there has been calculated detection limits for reporting inferior results (≥14 failures), and these limits are integrated in the NKLR database.
5. Paper II provides a newly developed individualized tool to help in the decision making in respect of patients' risk for developing degenerative changes.
6. Paper III provides reliable KOOS values for ACL injured individuals, both pre-operative and post-operative. New reference values for all three Scandinavian countries are displayed.
7. Paper III demonstrates that the three Scandinavian ACL registries are comparable and thus will be the best source for data on performance of a wide range of different implants and techniques.
8. Paper IV demonstrates the benefits of having a reliable national registry (NKLR) versus an American registry (MOON) that is not representative for the American population. Significant diversity in patient, injury, and surgical factors exist among large prospective cohorts collected in different locations. Surgeons should investigate the patient and surgical characteristics of such databases before applying knowledge from these groups to their own patient populations.

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Appendix

HELSE BERGEN
Haukeland Universitetssykehus

KOOS – Spørreskjema for knepasienter.

NASJONALT KORSBÅNDSREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 11
5021 BERGEN Tlf: 55976450

DATO: _____ **OPERASJONSDATO**: _____

FØDSELSNR (11 siffer): _____

NAVN: _____

SYKEHUS:_____

Veiledning: Dette spørreskjemaet inneholder spørsmål om hvordan du opplever kneet ditt før operasjonen. Informasjonen vil hjelpe oss til å følge med i hvordan du har det og fungerer i ditt daglige liv. Besvar spørsmålene ved å krysse av for det alternativ du synes stemmer best for deg (kun ett kryss ved hvert spørsmål). Hvis du er usikker, kryss likevel av for det alternativet som føles mest riktig.

KRYSS AV FOR RIKTIG KNE (NB: Ett skjema for hvert kne**):**☐[1] **VENSTRE** ☐[0] **HØYRE**

Røyker du? ☐[0] Nei ☐[1] Av og til ☐[2] Daglig
Hvis du røyker daglig –
hvor mange sigaretter per dag: _____

Vekt: _____ kg

Høyde :_____ cm

Symptom

Tenk på **symptomene** du har hatt fra kneet ditt den **siste uken** når du besvarer disse spørsmålene.

S1. Har kneet vært hovent?

Aldri	Sjelden	I blant	Ofte	Alltid
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S2. Har du følt knirking, hørt klikking eller andre lyder fra kneet?

Aldri	Sjelden	I blant	Ofte	Alltid
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S3. Har kneet haket seg opp eller låst seg?

Aldri	Sjelden	I blant	Ofte	Alltid
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S4. Har du kunnet rette kneet helt ut?

Alltid	Ofte	I blant	Sjelden	Aldri
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S5. Har du kunnet bøye kneet helt?

Alltid	Ofte	I blant	Sjelden	Aldri
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

Stivhet

De neste spørsmålene handler om **leddstivhet.** Leddstivhet innebærer vanskeligheter med å komme i gang eller økt motstand når du bøyer eller strekker kneet. Marker graden av leddstivhet du har opplevd i kneet ditt den **siste uken.**

S6. Hvor stivt er kneet ditt når du nettopp har våknet om morgenen?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S7. Hvor stivt er kneet ditt senere på dagen etter å ha sittet, ligget eller hvilt?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

LK1.0

Smerte

P1. Hvor ofte har du vondt i kneet?

Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐0	☐1	☐2	☐3	☐4

Hvilken grad av smerte har du hatt i kneet ditt den **siste uken** ved følgende aktiviteter?

P2. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P3. Rette kneet helt ut

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P4. Bøye kneet helt

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P5.Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P6. Gå opp eller ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P7. Om natten (smerter som forstyrrer søvnen)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P8. Sittende eller liggende

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P9. Stående

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Funksjon i hverdagen

De neste spørsmålene handler om din fysiske funksjon. **Angi graden av vanskeligheter du har opplevd den siste uken ved følgende aktiviteter på grunn av dine kneproblemer.**

A1. Gå ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A2. Gå opp trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A3. Reise deg fra sittende stilling

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Angi graden av **vanskeligheter** du har opplevd ved hver aktivitet den **siste uken.**

A4. Stå stille

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A5. Bøye deg, f.eks. for å plukke opp en gjenstand fra gulvet

Ingen	Lett	Moderat	Betydelig	Svært sto
☐0	☐1	☐2	☐3	☐4

A6. Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A7. Gå inn/ut av bil

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A8. Handle/gjøre innkjøp

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A9. Ta på sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A10. Stå opp fra sengen

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A11. Ta av sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A12. Ligge i sengen (snu deg, holde kneet i samme stilling i lengre tid)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A13. Gå inn/ut av badekar/dusj

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A14. Sitte

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A15. Sette deg og reise deg fra toalettet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A16. Gjøre tungt husarbeid (måke snø, vaske gulv, støvsuge osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A17. Gjør lett husarbeid (lage mat, tørke støv osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Funksjon, sport og fritid

De neste spørsmålene handler om din fysiske funksjon. **Angi graden av vanskeligheter du har opplevd den siste uken ved følgende aktiviteter på grunn av dine kneproblemer.**

SP1. Sitte på huk

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP2. Løpe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP3. Hoppe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP4. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP5. Stå på kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Livskvalitet

Q1. Hvor ofte gjør ditt kneproblem seg bemerket?

Aldri	Månedlig	Ukentlig	Daglig	Alltid
☐0	☐1	☐2	☐3	☐4

Q2. Har du forandret levesett for å unngå å overbelaste kneet?

Ingenting	Noe	Moderat	Betydelig	Fullstendig
☐0	☐1	☐2	☐3	☐4

Q3. I hvor stor grad kan du stole på kneet ditt?

Fullstendig	I stor grad	Moderat	Til en viss grad	Ikke i det hele tatt
☐0	☐1	☐2	☐3	☐4

Q4. Generelt sett, hvor store problemer har du med kneet ditt?

Ingen	Lette	Moderate	Betydelige	Svært store
☐0	☐1	☐2	☐3	☐4

Takk for at du tok deg tid og besvarte samtlige spørsmål!

Bergen Grafisk as - 23.05.07

NASJONALT
KORSBÅNDSREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 11
5021 BERGEN
Tlf: 55976450

DATO: _____

FØDSELSNR (11 siffer): _____

NAVN: _____

KOOS – Spørreskjema for knepasienter.

Veiledning: Dette spørreskjemaet inneholder spørsmål om hvordan du opplever kneet ditt nå. Informasjonen vil hjelpe oss til å følge med i hvordan du har det og fungerer i ditt daglige liv. Besvar spørsmålene ved å krysse av for det alternativ du synes stemmer best med deg (kun ett kryss ved hvert spørsmål). Hvis du er usikker, kryss likevel av for det alternativet som føles mest riktig.

KRYSS AV FOR RIKTIG KNE (NB: Ett skjema for hvert kne)**:** ☐[0] **VENSTRE** ☐[1] **HØYRE**

Røyker du? ☐[0] Nei ☐[1] Av og til ☐[2] Daglig Hvis du røyker daglig – hvor mange sigaretter per dag: _____	Vekt: _____ kg Høyde :_____ cm

Symptom

Tenk på **symptomene** du har hatt fra kneet ditt den **siste uken** når du besvarer disse spørsmålene.

S1. Har kneet vært hovent?

Aldri	Sjelden	I blant	Ofte	Alltid
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S2. Har du følt knirking, hørt klikking eller andre lyder fra kneet?

Aldri	Sjelden	I blant	Ofte	Alltid
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S3. Har kneet haket seg opp eller låst seg?

Aldri	Sjelden	I blant	Ofte	Alltid
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S4. Har du kunnet rette kneet helt ut?

Alltid	Ofte	I blant	Sjelden	Aldri
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S5. Har du kunnet bøye kneet helt?

Alltid	Ofte	I blant	Sjelden	Aldri
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

Stivhet

De neste spørsmålene handler om **leddstivhet.** Leddstivhet innebærer vanskeligheter med å komme i gang eller økt motstand når du bøyer eller strekker kneet. Marker graden av leddstivhet du har opplevd i kneet ditt den **siste uken.**

S6. Hvor stivt er kneet ditt når du nettopp har våknet om morgenen?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

S7. Hvor stivt er kneet ditt senere på dagen etter å ha sittet, ligget eller hvilt?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐[0]	☐[1]	☐[2]	☐[3]	☐[4]

Smerte

P1. Hvor ofte har du vondt i kneet?

Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐0	☐1	☐2	☐3	☐4

Hvilken grad av smerte har du hatt i kneet ditt **den siste uken** ved følgende aktiviteter?

P2. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P3. Rette kneet helt ut

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P4. Bøye kneet helt

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P5.Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P6. Gå opp eller ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P7. Om natten (smerter som forstyrrer søvnen)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P8. Sittende eller liggende

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

P9. Stående

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Funksjon i hverdagen

De neste spørsmålene handler om din fysiske funksjon. **Angi graden av vanskeligheter du har opplevd den siste uken ved følgende aktiviteter på grunn av dine kneproblemer.**

A1. Gå ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A2. Gå opp trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A3. Reise deg fra sittende stilling

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Angi graden av **vanskeligheter** du har opplevd ved hver aktivitet **den siste uken.**

A4. Stå stille

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A5. Bøye deg, f.eks. for å plukke opp en gjenstand fra gulvet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A6. Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A7. Gå inn/ut av bil

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A8. Handle/gjøre innkjøp

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A9. Ta på sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A10. Stå opp fra sengen

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A11. Ta av sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A12. Ligge i sengen (snu deg, holde kneet i samme stilling i lengre tid)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A13. Gå inn/ut av badekar/dusj

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A14. Sitte

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A15. Sette deg og reise deg fra toalettet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A16. Gjøre tungt husarbeid (måke snø, vaske gulv, støvsuge osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

A17. Gjør lett husarbeide (lage mat, tørke støv osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Funksjon, sport og fritid

De neste spørsmålene handler om din fysiske funksjon. **Angi graden av vanskeligheter du har opplevd den siste uken ved følgende aktiviteter på grunn av dine kneproblemer.**

SP1. Sitte på huk

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP2. Løpe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP3. Hoppe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP4. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

SP5. Stå på kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐0	☐1	☐2	☐3	☐4

Livskvalitet

Q1. Hvor ofte gjør ditt kneproblem seg bemerket?

Aldri	Månedlig	Ukentlig	Daglig	Alltid
☐0	☐1	☐2	☐3	☐4

Q2. Har du forandret levesett for å unngå å overbelaste kneet?

Ingenting	Noe	Moderat	Betydelig	Fullstendig
☐0	☐1	☐2	☐3	☐4

Q3. I hvor stor grad kan du stole på kneet ditt?

Fullstendig	I stor grad	Moderat	Til en viss grad	Ikke i det hele tatt
☐0	☐1	☐2	☐3	☐4

Q4. Generelt sett, hvor store problemer har du med kneet ditt?

Ingen	Lette	Moderate	Betydelige	Svært store
☐0	☐1	☐2	☐3	☐4

Tilleggsspørsmål

T1. Har du pådratt deg noen ny akutt skade i kneet etter korsbåndsoperasjonen?

☐[0] Nei

☐[1] Ja

T2. Hvis ja, hva slags skade (kryss av for hver skadetype, hvis flere strukturer er skadet):

☐[1] Fremre korsbånd Dato (mm.åå.):

☐[2] Bakre korsbånd Dato (mm.åå.):

☐[3] Andre leddbåndsskader Dato (mm.åå.):

☐[4] Meniskskade Dato (mm.åå.):

☐[5] Bruskskade Dato (mm.åå.):

☐[6] Bruddskade Dato (mm.åå.):

T3. Hvis du har pådratt deg en ny korsbåndsskade, hvordan ble diagnosen stilt:

☐[0] MR-undersøkelse (”magnetrøntgen”)

☐[1] Artroskopisk undersøkelse (”kikkhullsoperasjon”)

☐[2] Undersøkelse av lege

☐[3] Undersøkelse av annet helsepersonell (fysioterapeut, manuell terapeut etc.)

Takk for at du tok deg tid og besvarte samtlige spørsmål!

NASJONALT KORSBÅNDSREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 11, 5021 BERGEN
Tlf: 55976450

F.nr. (11 sifre).....

Navn.....

Sykehus.....

(Skriv tydelig ev. pasient klistrelapp – **spesifiser sykehus**.)

KORSBÅND

KORSBÅNDSOPERASJONER OG ALLE REOPERASJONER på pasienter som tidligere er korsbåndsoperert.

Alle klistrelapper (med unntak av pasientklistrelapp) settes i merket felt på baksiden av skjemaet.

(Bilateral operasjon = 2 skjema)

AKTUELL SIDE (ett kryss) ☐0 Høyre ☐1 Venstre
MOTSATT KNE ☐0 Normalt ☐1 Tidligere ACL/PCL-skade

TIDLIGERE OPERASJON I SAMME KNE (ev. flere kryss)
☐ ACL ☐ MCL ☐ PLC ☐ Medial menisk
☐ PCL ☐ LCL ☐ Brusk ☐ Lateral menisk
☐ Annet, spesifiser .....

SKADEDATO FOR AKTUELL SKADE (mm.åå) |__|__| |__|__|

AKTIVITET SOM FØRTE TIL AKTUELL SKADE
☐0 Fotball ☐6 Kampsport ☐13 Trafikk
☐1 Håndball ☐7 Basket ☐14 Volleyball
☐2 Alpint/Telemark ☐8 Langrenn/turski ☐15 Skateboard
☐3 Snowboard ☐9 Mosjonsaktiviteter ☐16 Trampoline
☐4 Ishockey/bandy/ rulleskøyter ☐10 Friluftsliv ☐17 Dans
☐11 Annen fritidsaktivitet ☐18 Motocross
☐5 Racketsport ☐12 Arbeid ☐19 Innebandy
☐98 Annet.....

AKTUELL SKADE (Registrer alle skader – også de som ikke opereres)
☐ ACL ☐ MCL ☐ PLC ☐ Menisk
☐ PCL ☐ LCL ☐ Brusk
☐ Annet.....

YTTERLIGERE SKADER (ev. flere kryss)

☐ Karskade	Hvilken: .....
☐ Nerveskade	☐ 0 N. tibialis ☐ 1 N. peroneus
☐ Fraktur	☐ 0Femur ☐ 1Tibia ☐ 2Fibula ☐ 3Patella ☐ 4Usikker
☐ Ruptur i ekstensorapparatet	☐ 0Quadricepssenen ☐ 1Patellarsenen

OPERASJONSDATO (dd.mm.åå) |__|__| |__|__| |__|__|

AKTUELLE OPERASJON (ett kryss)
(Hvis ingen kryss, gå direkte til ANDRE PROSEDYRER.)
☐0 Rekonstruksjon av korsbånd ☐1 Revisjonsrekonstruksjon

ÅRSAK TIL REVISJONSREKONSTRUKSJON (ev. flere kryss)
☐ Infeksjon ☐ Graftsvikt
☐ Fiksasjonssvikt ☐ Nytt traume
☐ Ubehandlede andre ligamentskader
☐ Annet .....

ANDRE PROSEDYRER (ev. flere kryss)
☐ Meniskoperasjon ☐ Osteosyntese
☐ Synovektomi ☐ Bruskoperasjon
☐ Mobilisering i narkose ☐ Artroskopisk debridement
☐ Fjerning av implantat ☐ Operasjon pga infeksjon
☐ Benreseksjon (Notch plastikk) ☐ Bentransplantasjon
☐ Osteotomi ☐ Artrodese
☐ Annet .....

GRAFTVALG (se forklaring på baksiden)

	ACL	PCL	MCL	LCL	PLC
☐ BPTB					
☐ ST – dobbel					
☐ ST – kvadruppel					
☐ STGR – dobbel					
☐ Double bundle- teknikk					
☐ BQT					
☐ BQT-A					
☐ BPTB-A					
☐ BACH-A					
☐ Direkte sutur					
☐ Syntetisk graft					
☐ Annet					

FIKSASJON
Sett klistrelapp på merket felt på baksiden av skjemaet
Skill mellom femur og tibia

AKTUELL BEHANDLING AV MENISKLESJON

	Reseksjon	Sutur	Syntetisk fiksasjon*	Menisk-transpl.	Trepanering	Ingen
Medial	☐	☐	☐	☐	☐	☐
Lateral	☐	☐	☐	☐	☐	☐

* Sett klistrelapp på merket felt på baksiden

BRUSKLESJON (ev. flere kryss. Husk å fylle ut arealet)
Er skaden: ☐ ny ☐ gammel ☐ vet ikke

	Omfang Areal (cm²) ≤2	>2	ICRS Grade* (1-4)	Sannsynlig årsak** (1-5)	Behandlings-kode*** (1-9)
Patella MF	☐	☐			
Patella LF	☐	☐			
Trochlea fem.	☐	☐			
Med. fem. cond.	☐	☐			
Med. tib. plat.	☐	☐			
Lat. fem. cond.	☐	☐			
Lat. tib. plat.	☐	☐			

***ICRS Grade:** 1 Nearly normal: Superficial lesions, soft indentation and/or superficial fissures and cracks; 2 Abnormal: Lesions extending down to <50% of cartilage depth; 3 Severely abnormal: Cartilage defects extending down >50% of cartilage depth as well as down to calcified layer; 4 Severely abnormal: Osteochondral injuries, lesions extending just through the subchondral boneplate or deeper defects down into trabecular bone.
****Sannsynlige årsaker:** 1 Traume; 2 CM: chondromalacia patellae; 3 OCD: osteochondritis dissecans; 4 OA: primær artrose; 5 Annet: Spesifiser årsak i aktuelle rubrikk
*****Behandlingskoder**: 1 Debridement; 2 Mikrofraktur; 3 Mosaikk; 4 Biopsi til dyrking; 5 Celletransplantasjon; 6 Celletransplantasjon med matrix; 7 Periosttransplantasjon; 8 Ingen behandling; 9 Annet: Spesifiser behandling i aktuelle rubrikk

DAGKIRURGISK OPERASJON ☐ 0 Nei ☐ 1 Ja

PEROPERATIVE KOMPLIKASJONER ☐ 0 Nei ☐ 1 Ja,
hvilke(n) .....

OPERASJONSTID (hud til hud).....min.

SYSTEMISK ANTIBIOTIKAPROFYLAKSE
☐0 Nei ☐1 Ja, Hvilken (A).....
Dose (A).....Totalt antall doser.....Varighet .....timer
Ev. i kombinasjon med (B).....
Dose (B).....Totalt antall doser.....Varighet .....timer

TROMBOSEPROFYLAKSE
☐0 Nei ☐1 Ja, hvilken type.....
Dosering opr.dag.....Første dose gitt preopr ☐0 Nei ☐1 Ja
Senere dosering.....Antatt varighet.....døgn
Ev. i kombinasjon med .....
Dosering.....Antatt varighet.....døgn
Annet, spesifiser .....

NSAIDs
☐0 Nei ☐1 Ja, hvilken type.....

Lege:.....
Legen som har fylt ut skjemaet (navnet registreres ikke i databasen).

Bergen Grafisk as - 08.02.08

RETTLEDNING

- Registreringen gjelder primæroperasjon eller reoperasjon av korsbåndsruptur (fremre og bakre).
- Registreringen gjelder også alle reoperasjoner på pasienter som tidligere er korsbåndsoperert.
- Ett skjema fylles ut for hvert kne som blir operert.
- Flere operasjoner i samme kne registreres på samme skjema.
- Aktuelle ruter markeres med kryss. I noen tilfeller skal det fylles inn et tall i rutene (Brusklesjon).
- Pasienten skal på eget skjema gi samtykke til registrering.

KOMMENTARER TIL DE ENKELTE PUNKTENE

TIDLIGERE OPERASJON I SAMME KNE

Forkortelser som er brukt under dette punktet og påfølgende punkter:

- ACL: Fremre korsbånd
- PCL: Bakre korsbånd
- MCL: Mediale kollateralligament
- LCL: Laterale kollateralligament
- PLC: Popliteus kompleks/bicepssene kompleks

SKADEDATO Skriv inn skadedatoen så eksakt som mulig. Ved ny skade av tidligere operert korsbånd, skriv inn den nye skadedatoen.

FIKSASJON Angi hvilken fiksasjonstype som er brukt ved å feste klistrelapp på baksiden. Husk å skille mellom femur og tibia.

GRAFTVALG Forkortelser som er brukt under dette punktet:

- BPTB; Patellarsene autograft
- ST: Semitendinosus autograft
- STGR: Semitendinosus + gracilis autograft
- BQT: Sentral quadricepssene autograft
- BQT-A: Sentral quadricepssene allograft
- BPTB-A: Patellarsene allograft
- BACH-A: Achilles allograft

PEROPERATIVE KOMPLIKASJONER

Ved en eventuell ruptur av høstet graft e.l. skal det her nevnes hva som var det opprinnelige graftet. Andre peroperative komplikasjoner skal også fylles inn her.

SYSTEMISK ANTIBIOTIKAPROFYLAKSE

Her føres det på hvilket antibiotikum som er blitt benyttet i forbindelse med operasjonen. Det anføres hvor stor dose, hvor mange doser og profylaksens varighet. Hvis en f.eks. kun har gitt 2g Keflin 4 ganger operasjons dagen med 4 timers mellomrom dvs. 12 timer mellom første og siste dose, så angis det i skjema: Hvilken (A) Keflin Dose(A) 2g Totalt antall doser 4 Varighet 12 timer.

Kopi beholdes til pasientjournalen, originalen sendes til Haukeland Sykehus.

Kontaktpersoner vedrørende registreringsskjema er
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Overlege Knut Andreas Fjeldsgaard, Haukeland Universitetssykehus, tlf.: 55 97 56 80,
e-post: knut.andreas.fjeldsgaard@helse-bergen.no
Sekretær i Nasjonalt Korsbåndsregister, Ortopedisk avd., Helse Bergen:
Ruth G Wasmuth, tlf.: 55 97 64 50, faks: 55 97 37 49
e-post: rgth@helse-bergen.no

GRAFTFIKSASJON		MENISKFIKSASJON	
FEMUR	**TIBIA**	**MEDIAL**	**LATERAL**

Paper I

Development of a National Cruciate Ligament Surgery Registry

The Norwegian National Knee Ligament Registry

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Background: No prospective surveillance system exists for monitoring the outcome of cruciate ligament surgery.

Purpose: This article is intended to describe the development and procedures of the Norwegian National Knee Ligament Registry (NKLR), including baseline results from the first 2 years of operation.

Study Design: Cohort study (prevalence); Level of evidence, 1.

Methods: The NKLR was established on June 7, 2004 to collect information prospectively on all cases of cruciate ligament reconstruction surgery in Norway. Information on the details of surgery is gathered through a registration form completed by the surgeon postoperatively, and a validated knee outcome score form is completed by the patients preoperatively and at follow-ups on all patients at 2, 5, and 10 years postoperatively. Hospital compliance was examined in 2005 and 2006.

Results: A total of 2793 primary cruciate ligament reconstruction surgeries were registered by 57 hospitals. This corresponds to an annual population incidence of primary anterior cruciate ligament reconstruction surgeries of 34 per 100 000 citizens (85 per 100 000 citizens in the main at-risk age group of 16-39 years). After 21 months of operation, the NKLR had an overall compliance of 97% when compared with the hospital records.

Conclusions: A national population-based cruciate ligament registry has been developed, implemented, and maintained in Norway. The registry will each year enroll approximately 1500 primary cruciate ligament reconstruction cases. It is expected that inadequate procedures and devices can be identified, as well as prognostic factors associated with good and poor outcomes, at least for the most frequent categories.

Keywords: orthopaedics; anterior cruciate ligament; registry; epidemiology; incidence; outcome

National quality registries have been used in several medical specialties to improve health care in Scandinavia,[1,15,20,21,24,27,28,33] including Norway.[3,17,21,23] Because of the inferior clinical results associated with some hip prosthesis designs in the early 1980s,[10] the nationwide Norwegian Hip Arthroplasty Register (NAR) was established in 1987 with implant revision as the main end point.[14] Its aim was the early detection of inferior results caused by implants, cements, or surgical techniques.[6,11] In 1994, the registry was expanded to include all joint replacements.[11] In 1995, 2 papers[12,13] were published that described the detection of inferior implants at an early stage, a finding only possible through registry studies.

The NAR is based on a simple reporting system (approximately 1 minute is required to complete a single-page registration form) and the hospitals are provided with continuous feedback from the registry.[11] These 2 factors are believed to explain why the compliance rate of nearly 100% has not declined during 20 years of operation.[4,11] Immediately after each operation, the surgeon completes the registration form, which is mailed to the NAR office.[14] Patient identification and the different procedures, including the type of implant and cement used, are specified on

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the registration form. Feedback is given as annual national reports. In addition, each hospital receives a report on its own activities and results, which can be compared with the national average. A wide range of studies have been published based on the NAR database.[11]

In contrast to joint replacement surgery, for which national registries have been established in Norway, Sweden (1979), Finland (1980), Denmark (1995), Australia (1999), New Zealand (1999), Canada (2000), Romania (2001), and England and Wales (2003), no national prospective surveillance system exists for monitoring the outcome of knee ligament surgery in a predefined population. Evidence from the Scandinavian joint replacement registries indicates that a national knee ligament registry could be highly beneficial.[12,13,16,26] First, treatment outcome can be improved through feedback to the hospitals and surgeons from the registries. Second, there are still several unresolved issues related to cruciate ligament surgery and postoperative rehabilitation methods. Some of these can and should be addressed by conducting properly designed randomized controlled trials. However, because of practical, financial, or other restraints, such studies are often not possible. Also, some questions can only be answered by large cohort studies. This includes the detection of procedures and devices that result in premature failure. Third, large cohort studies can be used to identify prognostic factors associated with good and poor outcomes.

This background served as the impetus for designing the Norwegian National Knee Ligament Registry (NKLR). This article describes the development and procedures of the first national knee ligament registry, including baseline results from the first 2 years of operation.

MATERIALS AND METHODS

Structure

A working group was established with members from NAR and the Oslo Sports Trauma Research Center (OSTRC) in 2002. The group designed the registry, constructed forms, planned the logistics, and contacted the hospitals. The NKLR is owned by the Norwegian Orthopaedic Association (NOA), and a steering committee with 6 members is appointed jointly by NOA and OSTRC. Since the official start on June 7, 2004, the steering committee has been responsible for the budget, planning, and continuous evaluation of the dataset.

Design

The NKLR is designed to collect information prospectively on all cases of cruciate ligament reconstruction surgery. To be included in the cohort, a patient should be a resident of Norway undergoing primary or revision reconstruction surgery for an anterior cruciate ligament (ACL) and/or posterior cruciate ligament (PCL) injury at a Norwegian hospital. In addition, the NKLR also records all surgical procedures to a knee joint that has previously undergone primary or revision ACL and/or PCL reconstruction surgery.

Participation is voluntary, and all patients are asked to sign an informed consent form before surgery. The consent form contains information about the NKLR, the type of information recorded, data protection, and the procedure for follow-ups, and informs the patient that he or she may be invited to participate in research projects at a later stage. The patients are also asked to complete a validated knee outcome score form, the Knee injury and Osteoarthritis Outcome Score (KOOS).[22] The KOOS form is a knee-specific instrument, developed to assess patients' opinion about their knees and associated problems, and was intended to be used for knee injuries that could result in posttraumatic osteoarthritis.

The form includes 42 items in 5 separately scored subscales: pain (9 items), other symptoms (7 items), function in activities of daily living (17 items), function in sport and recreation (5 items), and knee-related quality of life (4 items). Each item is responded to by marking 1 of 5 response options on a Likert scale. The Western Ontario and McMaster Universities (WOMAC) LK 3.0^2 items are included in the first 3 KOOS subscales. The KOOS is valid and reliable for short-term and long-term follow-up studies of knee injury and osteoarthritis.[30-32] It is also valid for patients in the age group 14 to 78 years of age. The KOOS was considered reliable and responsive for assessment of knee complaints in a recent comparative review of knee-specific outcome measures.[7] Confidentiality is ensured for patients and individual surgeons. The study has been approved by the Data Inspectorate as an expansion of the NAR concession.

The registry makes use of both objective and subjective end points. Similar to NAR, the hard end points are revision surgery after cruciate ligament surgery and total knee replacement. Unlike NAR, the NKLR will include routine follow-ups on all patients at 2, 5, and 10 years postoperatively using KOOS score as a soft end point. The KOOS form will be dispatched from the NKLR secretariat at the time for follow-ups. The NKLR will offer different ways of returning the completed KOOS forms, such as regular mail and Internet, as an attempt to ensure a high compliance rate. The KOOS form is not returned to the patient if incomplete. Missing data are treated according to the guidelines for KOOS score calculation.[31]

Registration Process

After pilot testing at 3 hospitals, the registration form (Appendix 1) has been developed to collect information on the details of surgery. One form is completed for each knee joint undergoing surgical treatment. Similar to NAR, the form is completed by the surgeon immediately after surgery has been performed.

The data items recorded are a minimal set suited for a paper-based or web-based reporting system, not to exceed 1 page. The items were chosen based on the following 3 criteria. Can the question addressed be clearly specified and justified? Is the question clinically relevant? Can the item be completed postoperatively while dictating the surgery notes, not needing to seek information from other sources?

Cartilage lesions are graded according to the International Cartilage Repair Society.[34] To obtain accurate information on the different fixation devices, it is recommended that the surgeon report the catalog number of each device by using the unique bar-code stickers delivered by the manufacturers. The stickers contain all vital information about the device. The surgeon signs the form, but the surgeon's identity is not recorded, and thus cannot be traced in the registry.

One copy of the registration form is sent to NKLR and the original is retained in the patient's hospital chart. On arrival at the NKLR, the KOOS and registration forms are checked for completeness and entered into a computerized data management system. This is developed as an Oracle database (Oracle Corporation, Redwood Shores, Calif) with clerical and electronic data checks, as well as automated coding and reporting facilities. After registration, the data are further checked to ensure the quality, eliminate possible duplicates and illogical combinations in the form, and ensure conformity between registration and KOOS forms.

A copy of the registration form is returned to the hospital if the form is incomplete (eg, if essential data such as the date of operation or the social security number are missing). If the form is not returned after 1 reminder or the data cannot be found, the form is marked as incomplete and labeled "missing" for the missing data, thus retaining the possibility of using incomplete forms in the analysis.

The patients are identified by their unique social security number (including date of birth), which is assigned to all Norwegian residents. The social security number is used to link the KOOS and registration forms, and to update the registry annually with death and emigration data before extracting data files for analysis.

Compliance

A first baseline compliance study was carried out in March 2005 covering the period October 1, 2004 through February 28, 2005. The study covered primary ACL reconstructions and ACL revision surgeries, not other procedures. Data from the NKLR were compared with the Norwegian Patient Register (NPR), which has been established by the Ministry of Health and Social Services to provide statistics from the Norwegian hospital sector, as well as with patient data from hospital records. The NPR has been used as a gold standard by NAR.[4] Ten hospitals participated, representing all 5 health regions, hospitals with large and small volumes (cut-off was set at 30 annual ACL procedures), public and private hospitals, and hospitals with and without surgeons who were involved in developing NKLR. Based on preliminary data, we estimated that at least 250 cases could be expected from these hospitals, which would give the study sufficient power. All of the 10 invited hospitals agreed to participate.

A second study was performed in 2006 covering the period October 1, 2005 through February 28, 2006. This study used the same procedures as described for the baseline compliance study with 2 exceptions. Some of the hospitals dispatched the data electronically (electronic patient journals), and the surgical log books were used as the gold standard. This study covered 14 randomly chosen hospitals participating in the NKLR.

Research and Information

Requests for data from the NKLR are encouraged, and data files are returned to the surgeon or hospital in question after approval of a written request addressed to the steering committee. Only the official hospital contact can ask for patient-identifiable information from his or her own hospital. Some legal restrictions exist, primarily the combination of NKLR with other population-based registries in Norway. Requests for more extensive data for research projects also require a written application to the steering committee. If external researchers wish to combine data from the NKLR with their own data files, specific approval is required from the Data Inspectorate and the appropriate Regional Committee for Medical Research Ethics.

Descriptive national data are provided in an annual report, which is sent to all members of the NOA, all hospitals performing cruciate ligament surgery, and to the health authorities. This report is also published on the joint website of NAR and NKLR (www.haukeland.no/nrl). In addition, each participating hospital will receive descriptive statistics and outcome data for their own hospital, which they can compare with the national report.

Staff and Operating Costs

The NKLR employs a secretary (50% position), a computer engineer (50%), and an orthopaedic surgeon (20%) as the administrative head of NKLR. In addition, each hospital provides secretarial assistance amounting to approximately 10% of a full position. The total operating budget for 2006 for the central NKLR office is 527 000 krones (approximately 67 000 euros, or 91 000 US dollars). This cost does not include salary for additional staff involved in various research projects based on the NKLR. It is expected that the basic operating costs will increase somewhat as the cohort and number of follow-ups increase year by year.

RESULTS

Descriptive Data

From June 7, 2004, until May 24, 2006 (687 days), 2793 primary cruciate ligament reconstruction surgeries were registered by 57 hospitals. This corresponds to an annual rate of 1484 primary cruciate ligament reconstructions in Norway, 1168 of them in the age group 16 through 39 years (the main population at risk). In 2005, there were 4 393 000 citizens in Norway, 1 382 000 of them aged 16 through 39 years. Thus, the annual population incidence of primary ACL reconstruction surgeries was 34 per 100 000 citizens, while the incidence in the 16 to 39 years age group was 85 per 100 000 citizens.

Of the 2793 cases recorded in the NKLR, 2714 were primary ACL reconstructions, 25 were primary PCL reconstructions, and 54 were combined primary reconstructions of both cruciate ligaments.

How Complete Are the Data?

The baseline compliance study identified 285 cases in the NKLR database, 332 in the hospital protocols, and 339 at

TABLE 1
Patient Characteristics for All Primary Cruciate Ligament Reconstruction Surgery Cases[a]

Characteristics	ACL (n = 2714)	PCL (n = 25)	ACL and PCL (n = 54)
Sex (% male)	57	72	59
Age (median, range)	27 (12-67)	28 (17-57)	34 (15-36)
Previous ACL or PCL injury to opposite knee	191	0	4
Most frequent activities causing injury	Soccer (n = 1088) Team handball (n = 413) Alpine skiing (n = 270)	Traffic (n = 8) Soccer (n = 7)	Traffic (n = 15) Cross-country skiing (n = 10) Alpine skiing (n = 6)
Median time to surgery in months (range)	7 (0-416)	13 (6-170)	7 (0-104)
Outpatient surgery (%)	35	0	4
Perioperative complications (%)[b]	5	0	0
Prophylactic antibiotics (%)	99	100	100
Prophylactic anticoagulation (%)[c]	77	90	94

[a]ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.
[b]Most often due to failure of devices or grafts.
[c]Incorporated into the form January 2005.

TABLE 2
Group-Specific Preoperative KOOS Scores[a]

Subscale	Primary ACL Group (n = 2426)	Primary PCL Group (n = 24)	Primary ACL and PCL Group (n = 51)
Pain	72.9 ± 18.2	62.6 ± 17.9	69.2 ± 25.8
Symptoms	71.5 ± 17.8	71.1 ± 15.6	72.3 ± 18.9
Activities of daily living	81.2 ± 18.4	75.2 ± 16.2	68.4 ± 27.3
Sports/recreation	40.9 ± 26.5	35.2 ± 25.0	31.3 ± 32.2
Quality of life	34.0 ± 18.2	33.1 ± 15.4	31.9 ± 28.9

[a]Data are shown as the mean with standard deviation for each subscore.
KOOS, Knee injury and Osteoarthritis Outcome Score; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

the NPR. Thus, after 4 to 9 months of operation, the NKLR had a compliance of 84% in relation to the NPR among the hospitals participating. At this time, 51 out of a possible total of 56 hospitals and clinics (91%) took part.

The second compliance study identified 195 cases in the NKLR database, 202 in the protocols at the hospitals, and 181 at the NPR (1 private hospital with 18 cases recorded in the NKLR database did not report to the NPR). Thus, after 16 to 21 months of operation, the NKLR had compliance of 97% and 98% in relation to the hospital protocols (195/202) and NPR (177/181), respectively. By the end of the study period, all hospitals and clinics (N = 57) participated in the NKLR, although the last hospital was not included until the final 2 months of the second compliance study period.

Primary ACL Reconstructions

A total of 2714 primary ACL reconstruction surgeries were performed at 57 different hospitals. Of these, 1717 patients (63%) underwent surgery within a year of the index injury, while 285 (11%) waited more than 5 years before surgery (101 cases have missing information). The characteristics and preoperative KOOS scores for this group are outlined in Tables 1 and 2. Patients who had waited more than 5 years before surgery did not differ significantly in their KOOS scores from the rest of the patients with primary ACL reconstructions (data not shown). A total of 578 patients (21%) had previously undergone surgery (all specified) to the index knee. In 10 cases (<1%), a PCL injury was also reported, but not treated surgically. In 27 cases (1%), a lateral collateral ligament (LCL) injury was reported, while a medial collateral ligament (MCL) injury was reported in 129 cases (5%). A total of 1287 cases (47%) had associated meniscal tears; 90% of these were treated surgically.

Cartilage lesions were reported in 712 knees (26%), and 59% of these were treated surgically. When grading the cartilage lesions, 222 cases (31%) were classified as grade 1, 283 (40%) as grade 2, 151 (21%) as grade 3, and 49 (7%) as grade 4; 7 cases had missing grading. In 392 cases (55%), the largest lesion measured 2 cm^2 or less, while in 271 cases (38%), at least 1 lesion was greater than 2 cm^2 (49 knees with cartilage lesions did not report measurements). A total of 80 patients (11%) had grade 3 or 4 cartilage lesions of more than 2 cm^2.

In 1105 cases (41%), a bone–patellar tendon–bone autograft was used, while a hamstring autograft was used in 1597 cases (59%). Only 11 (<1%) of the primary ACL reconstruction surgeries were done with other graft types. The number of different fixation devices used is shown in Table 3.

Primary PCL Reconstructions

A total of 25 primary PCL reconstruction surgeries were performed by 4 different hospitals. Of these, 10 patients (40%) received surgery within a year of the index injury, while 5 (20%) waited more than 5 years before surgery. The

TABLE 3
The Number of Different Devices Used on the Femur and Tibia for ACL and PCL Fixation[a]

	ACL		PCL	
	Femur Fixation	Tibia Fixation	Femur Fixation	Tibia Fixation
ACL	29	33	7	11
PCL	6	4	10	7
MCL	4	4	2	1
LCL	1	1	1	1
PLC	1	2	1	2

[a]The data are based on all primary (N=2793) or revision (N=31) reconstruction surgery cases.

ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; MCL, medial collateral ligament; LCL, lateral collateral ligament; PLC, posterolateral corner.

characteristics and preoperative KOOS scores for this group are outlined in Tables 1 and 2. A total of 3 patients (12%) had previously undergone surgery (all specified) to the index knee. In 2 cases (4%), a posterolateral corner (PLC) injury was reported, while an MCL injury was reported in 5 cases (20%). Two cases (8%) had associated meniscal tears; neither of these were treated surgically.

Cartilage lesions were reported in 10 knees (40%), and 40% of these were treated surgically. When grading the cartilage lesions, 8 cases (80%) were classified as grade 2, and 2 (20%) as grade 3. In 2 cases (20%), the largest lesion measured 2 cm^2 or less, while in 8 cases (80%) at least 1 lesion was greater than 2 cm^2. One patient (4%) had grade 3 or 4 cartilage lesions of more than 2 cm^2.

In 4 cases (16%), a bone–patellar tendon–bone autograft was used, while a hamstring autograft was used in 19 cases (76%). Only 2 (8%) of the primary PCL reconstruction surgeries were done with other graft types.

Combined Primary ACL and PCL Reconstructions

A total of 54 combined primary ACL and PCL reconstruction surgeries were performed by 6 different hospitals. Of these, 38 patients (70%) received surgery within a year of the index injury, while 3 (6%) waited for more than 5 years before surgery. The characteristics and preoperative KOOS scores for this group are outlined in Tables 1 and 2. A total of 4 patients (7%) had previously undergone surgery (all specified) to the index knee. In 18 cases (33%), a PLC injury was reported; in 4 cases (7%), an LCL injury was reported; and an MCL injury was reported in 30 cases (56%). A total of 17 cases (31%) had associated meniscal tears; 82% of these were treated surgically.

Cartilage lesions were reported in 26 knees (48%), and 35% of these were treated surgically. When grading the cartilage lesions, 3 cases (12%) were classified as grade 1, 10 (38%) as grade 2, 9 (35%) as grade 3, and 4 (15%) as grade 4. In 9 cases (35%), the largest lesion measured 2 cm^2 or less, while in 17 cases (65%) at least 1 lesion was greater than 2 cm^2. Eight patients (31%) had grade 3 or 4 cartilage lesions of more than 2 cm^2.

In 41 of the 54 combined cases (76%) a bone–patellar tendon–bone autograft was used to reconstruct the ACL, while a hamstring autograft was used in 10 cases (19%) and other graft types were used in 3 cases (6%). To reconstruct the PCL, a bone–patellar tendon–bone autograft was used in 1 case (2%), a hamstring autograft was used in 37 cases (69%), another graft type was used in 7 cases (13%), while in 9 cases (17%) the PCL injury was not reconstructed.

Revision ACL and/or PCL Reconstructions

A subgroup of 31 of the 2793 patients (1.1%) included from the start of the NKLR was recorded as undergoing cruciate ligament revision surgery during the period. Of these, there are 28 patients from the primary ACL surgery group, 2 from the primary PCL surgery group, and 1 from the group that had primary reconstruction of both the ACL and PCL. The median time to revision surgery was 300 days (range, 2-593). There was no difference in their preoperative KOOS score between primary surgery and revision surgery (data not shown).

DISCUSSION

This article describes the development of the world's first national cruciate ligament surgery registry, its design, procedures, and characteristics of patients included. The results show that in 2 years of operation, nearly all patients undergoing cruciate ligament surgery were included in the registry. Based on these data, it may be expected that the NKLR each year will enroll approximately 1460 primary ACL reconstruction cases, 10 primary PCL reconstructions, and 30 combined primary reconstructions. In the future, the registry will also record revision reconstruction surgery and other surgical procedures to all knee joints previously recorded in the registry.

Patient registries are established to improve the standard of health care. Specifically, they are meant to serve 3 purposes: to improve treatment outcomes through feedback to the hospitals and surgeons, to detect procedures and devices that result in premature failure, and to identify prognostic factors associated with good and poor outcomes. However, to serve these purposes, the accuracy of the outcome measures used is critical. The joint registries, including NAR, only use revision surgery as an end point. Thus, patients may have a poor result without this being registered. In contrast, in addition to revision surgery, NKLR also includes routine follow-ups with patient-reported KOOS scores as the primary end point. The KOOS scores are collected preoperatively from the patients, as well as after 2, 5, and 10 years postoperatively. The intention is to detect inferior results and early failures, regardless of whether patients with a failed graft decide to go through revision surgery or not. Also, at a later stage, data from NKLR can be combined with data from NAR on knee arthroplasties, thus using surgically verified severe osteoarthritis as an additional end point.

The choice of the KOOS form over other alternatives took a number of elements into consideration: The form

should be patient-based to allow for nonbiased outcome data. The form should be self-explanatory, and time required to complete the form should be kept to a maximum of 10 minutes to ensure good compliance at follow-ups. Finally, the form had to be validated for cruciate ligament surgery. These requirements left us with two choices: KOOS or International Knee Documentation Committee (IKDC) 2000.[18,19] We chose the KOOS form because, in our opinion, it is far more user-friendly from a patient's perspective than the IKDC 2000. However, it remains to be seen how well patients will comply with the follow-up procedures.

To serve its first purpose, to improve treatment outcomes through continuous feedback to the participating hospitals, each year hospitals are provided with results on their own patients and national data. This is based on the idea that hospitals able to compare their outcomes with national averages will improve by following the better examples. An annual report is sent to all the members of the NOA, to all hospitals performing cruciate ligament surgery, and to the health authorities, and also published on the joint website of NAR and NKLR (www.haukeland.no/nrl). The NKLR depends on participation from all orthopaedic surgeons performing cruciate ligament surgery, including those normally not involved in research. Feedback is therefore also important to maintain motivation and interest in the registry, and we believe the reporting procedure explains the high compliance with the registry observed. Based on our previous experience with NAR, it may be expected that compliance will remain high. This is based on the premise that there will be no additional demands on the surgeons except filling out the forms, and that NKLR will serve the hospitals with clinically relevant and important information.

The second purpose, to detect procedures and devices that result in premature failure, can be achieved based on revision surgery or, if a revision has not been performed, deterioration of the KOOS score.[29] The following example illustrates this point. A score of at least 60 points may be expected with a successful outcome after surgery.[31] Age- and sex-specific general population reference values are also available for all 5 KOOS subscales.[29] A change in the KOOS score of 10 points can be considered a clinically significant difference—as an improvement after surgery or deterioration after graft failure.[29] Thus, the number of patients needed to detect failure in a cohort study may be calculated. Assuming a more conservative estimate, that a difference of 20 points is sufficient to predict an inferior device or procedure, as few as 14 failures are needed, using standard statistical values. These estimates also apply if the purpose is to discover prognostic factors that are associated with good or poor outcomes. For example, there are many patients with large cartilage lesions (>2 cm^2) and lesions graded 3 or 4 that are of special interest as their treatment outcome may be less predictable. Thus, because it may be estimated that the registry will include 2-year outcome data on at least 6500 patients with isolated ACL reconstructions after 7 years of operation, it seems reasonable to assume that the registry will be able to provide relevant data on inadequate procedures and devices. However, less common procedures and devices will be difficult to assess, and it should be noted that the frequency of devices in use varies considerably (Table 3). Also, as shown in the results, isolated PCL reconstructions and combined ACL/PCL reconstructions are much less frequent than isolated ACL reconstructions, and for these procedures it will be difficult to study subgroups, even with a national registry. However, this may be achieved when the registries of Sweden, Denmark, and Norway are combined.

It may be argued that randomized controlled trials (RCTs) are better than cohort studies to assess the outcome of cruciate ligament surgery. Although RCTs are preferable to address specific research questions, such as comparing 1 surgical procedure to another, they are difficult to organize, time-consuming, and costly. Therefore, it is often not possible or even justified to conduct an RCT to address anything but major differences in procedures or devices. One example may be minor changes in screw design or materials. A national registry can be used to assess results with minimal additional work or cost. However, it should be noted that in a nonrandomized cohort study, confounding factors must be adjusted for, either by selection of homogeneous subgroups or by use of a multiple regression model when analyzing the results.[12]

An important limitation of the registry is that only surgically treated cruciate injuries are included. Some studies have shown that most cruciate ligament-injured patients will see medical care and thus could be entered into the registry.[9] However, because of logistic and diagnostic issues, we have decided to not include this group at this stage.

The annual Norwegian population incidence of primary ACL reconstruction surgeries was 34 per 100 000 citizens, while the incidence in the 16- to 39-year-old age group was 85 per 100 000 citizens, both higher than previously published. Based on a questionnaire to all Norwegian hospitals in 2001 and 2002-2003, we estimated the annual incidence to be 42 ACL surgeries per 100 000 citizens.[8] However, because we do not know the ratio of surgically treated versus conservatively treated cases, the population incidence of ACL injuries is not known. In Germany, this has been estimated to be 32 per 100 000 citizens in the general population, and 70 per 100 000 citizens among the more physically active.[25] A recent study from 1 emergency department in Sweden reported that the physically active population between 10 to 64 years of age had an annual incidence of ACL injuries of 81 per 100 000 citizens.[5] However, the present study is the first extensive and complete population-based survey and from our data it appears that the true population incidence may be 50% to 100% higher, as in our experience as many as 30% to 50% of all ACL-injured subjects do not undergo surgery.

In conclusion, this study shows that a national population-based cruciate ligament registry could be developed, implemented, and maintained in Norway, providing data on more than 95% of all patients undergoing cruciate ligament surgery. The registry will each year enroll approximately 1460 primary ACL reconstruction cases, 10 primary PCL reconstruction cases, and 30 cases of primary reconstruction of both cruciate ligaments. It may be expected that the registry can enable us to identify inadequate procedures and devices,

as well as prognostic factors associated with good and poor outcomes, at least for the most frequent categories.

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APPENDIX

NATIONAL KNEE LIGAMENT REGISTRY
Norwegian Arthroplasty Register
Department of Orthopedic Surgery
Haukeland University Hospital
Møllendalsbakken 11
N-5021 BERGEN, NORWAY
Tlf: (+47) 55976450

Patient ID and date of birth (11 digits).....

Name.....

Hospital.....

CRUCIATE LIGAMENTS

CRUCIATE LIGAMENT SURGERY AND ALL REVISIONS on patients with previous cruciate ligament surgery.
All stickers (except patient ID) are pasted in predefined columns on the back of the form.

INDEX SIDE (mark one) (Bilateral surgery= 2 forms)
☐0 Right ☐1 Left

OPPOSITE KNEE ☐0 Normal ☐1 Previous ACL/PCL-injury

PREVIOUS SURGERY IN INDEX KNEE (one or more)
☐ ACL ☐ MCL ☐ PLC ☐ Medial meniscus
☐ PCL ☐ LCL ☐ Cartilage ☐ Lateral meniscus
☐ Other, specify .....

DATE OF INJURY (mm.yy) |__|__|__|__|

ACTIVITY THAT LEAD TO INJURY
☐0 Soccer ☐6 Martial arts ☐12 Work
☐1 Handball ☐7 Basketball ☐13 Traffic
☐2 Alpine skiing ☐8 Cross country skiing ☐14 Volleyball
☐3 Snowboard ☐9 Recreational activities ☐15 Skateboard
☐4 Ishockey/bandy/ inline skating ☐10 Outdoor life ☐16 Trampoline
☐5 Racket sports ☐11 Other recreational activities ☐17 Dance

☐98 Other.....

ACTUAL INJURY (Register all injuries – independent of surgery)
☐ ACL ☐ MCL ☐ PLC ☐ Menisci
☐ PCL ☐ LCL ☐ Cartilage
☐ Other.....

FURTHER INJURIES (none, one or more)

	Specify:
☐ Vasular	
☐ Nerve	☐ 0 N. tibialis ☐ 1 N. peroneus
☐ Fracture	☐ 0Femur ☐ 1Tibia ☐ 2Fibula ☐ 3Patella ☐ 4Not sure
☐ Rupture in extensor apparatus	☐ 0Quadriceps tendon ☐ 1Patellar tendon

DATE OF SURGERY (dd.mm.yy) |__|__|__|__|__|__|

ACTUAL SURGERY (mark one)
(If none, skip to the next question)
☐0 Reconstruction of cruciate ligament ☐1 Revision

OTHER PROCEDURES (none, one or more)
☐ Meniscus surgery ☐ Osteosynthesis
☐ Synovectomy ☐ Cartilage surgery
☐ Mobilizing in narcosis ☐ Arthroscopic débridement
☐ Remove implant ☐ Surgery due to infection
☐ Bone resection (Notchplasty) ☐ Bone transplantation
☐ Osteotomy ☐ Artrodesis
☐ Other .....

CHOICE OF GRAFT (see back for instructions)

	ACL	PCL	MCL	LCL	PLC
☐ BPTB					
☐ ST – double					
☐ ST – quadruple					
☐ STGR – single					
☐ STGR – double					
☐ STGR - quadruple					
☐ BQT					
☐ BQT-A					
☐ BPTB-A					
☐ BACH-A					
☐ Suture					
☐ Synthetic graft					
☐ Other					

FIXATION DEVICES
Paste stickers in predefined columns on the back of the form
Differentiate between femur and tibia

ACTUAL TREATMENT OF MENISCAL LESION

	Resection	Suture	Synthetic fixation*	Meniscus Transplant.	Tre-panation	None
Med.	☐	☐	☐	☐	☐	☐
Lat.	☐	☐	☐	☐	☐	☐

* Paste stickers in predefined columns on the back of the form

CARTILAGE LESION (none, one or more. Remember to fill in the area)
Injury: ☐ new ☐ old ☐ undefined

	Size Area (cm^2) ≤2	>2	ICRS Grade* (1-4)	Probable cause** (1-5)	Treatment code*** (1-9)
Patella MF	☐	☐			
Patella LF	☐	☐			
Trochlea fem.	☐	☐			
Med. fem. cond.	☐	☐			
Med. tib. plat.	☐	☐			
Lat. fem. cond.	☐	☐			
Lat. tib. plat.	☐	☐			

***ICRS Grade:** 1 Nearly normal: Superficial lesions, soft indentation and/or superficial fissures and cracks; 2 Abnormal: Lesions extending down to <50% of cartilage depth; 3 Severely abnormal: Cartilage defects extending down >50% of cartilage depth as well as down to calcified layer; 4 Severely abnormal: Osteochondral injuries, lesions extending just through the subchondral boneplate or deeper defects down into trabecular bone.
** **Probable cause:** 1 Trauma; 2 CM: chondromalacia patellae; 3 OCD: osteochondritis dissecans; 4 OA: primary osteoarthritis; 5 Other: Specify cause in correct column
*** **Treatment code**: 1 Debridement; 2 Microfracture; 3 Mosaic; 4 Biopsy for cultivation; 5 Cell transplantation; 6 Cell transplantation with matrix; 7 Periosteum transplantation; 8 No treatment; 9 Other: Specify cause in correct column

OUTPATIENT SURGERY ☐0 No ☐1 Yes

PER OPERATIVE COMPLICATIONS ☐0 No ☐1 Yes,
which.....

DURATION OF SURGERY (skin to skin-time).....min.

SYSTEMIC ANTIBIOTIC PROPHYLAXIS ☐0 No ☐1 Yes
Name (A) .....
Dosage (A)..... Total number of dosages .....Duration .....hours
.....
Dosage (B)..... Total number of dosages .....Duration .....hours

TROMBOSIS PROPHYLAXIS
☐0 No
☐1 Yes, name .....
Dosage ..... Duration.....days
First dosage given preoperative ☐0 No ☐1 Yes
If second prophylaxis is used: .....
Dosage ..... Duration.....days
Stocking ☐0 No ☐1 Calf ☐2 Thigh Duration.....days
Other, specify .....

Surgeon:.....
Surgeon that filled in the form (surgeon's name is not registered).

Paper II

Timing of Anterior Cruciate Ligament Reconstructive Surgery and Risk of Cartilage Lesions and Meniscal Tears

A Cohort Study Based on the Norwegian National Knee Ligament Registry

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Background: There is inadequate evidence to determine when to perform surgery on anterior cruciate ligament–deficient knees.

Purpose: To study the association between timing of anterior cruciate ligament reconstruction and the risk of having meniscal tears and cartilage lesions.

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: All patients registered in the Norwegian National Knee Ligament Registry who had undergone primary anterior cruciate ligament reconstruction from 2004 and throughout 2006 were reviewed. Logistic regression analyses were used to estimate the relationship between time from injury until anterior cruciate ligament surgery and the risk of meniscal tears or cartilage lesions.

Results: Of a total of 3475 patients, there were 909 patients (26%) with cartilage lesions, 1638 patients (47%) with meniscal tears, and 527 patients (15%) with both cartilage and meniscal lesions. The odds of a cartilage lesion in the adult knee (>16 years) increased by 1.006 (95% confidence interval, 1.003-1.010) for each month that elapsed from injury to surgery. The cartilage in young adults (17-40 years) deteriorated further with an increase in odds of 1.03 (95% confidence interval, 1.02-1.05) related to the aging in years of the patient. The odds for meniscal tears in young adults increased by 1.004 (95% confidence interval, 1.002-1.006) for each month that elapsed since injury. The presence of 1 degenerative lesion increased the odds of having the other degenerative lesion by between 1.6 and 2.0 in all patient groups.

Conclusion: The odds of a cartilage lesion in the adult knee increased by nearly 1% for each month that elapsed from the injury date until the surgery date and that of cartilage lesions were nearly twice as frequent if there was a meniscal tear, and vice versa.

Keywords: registry; anterior cruciate ligament (ACL); timing; meniscal tears; cartilage lesions

The decision on when to perform surgery on an ACL-deficient knee varies among knee surgeons. Whereas there is some agreement on being conservative and delaying surgery in children with open physes until skeletal maturity is reached,[10] timing of surgery in the adult population varies from the very first day after the injury to several years due to a long waiting list or the choice of the patient or surgeon. Surgery was frequently done acutely in the late 1970s and early 1980s, but a study by Shelbourne et al[14] from 1991 on avoiding arthrofibrosis changed the field from a time-dependent to a function-dependent timing of surgery. Their data suggested that surgery should be performed after the swelling has subsided and range of motion is normal. A

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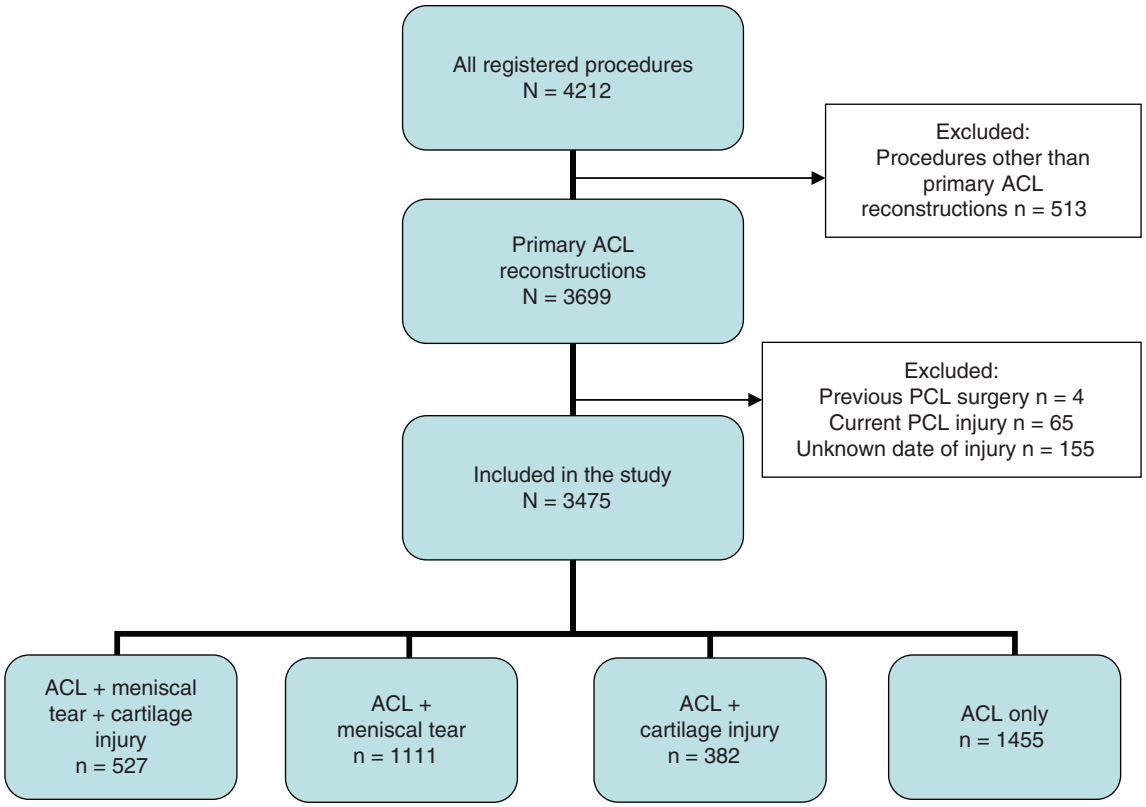

Figure 1. Patient distribution and exclusion criteria.

review of the literature on the treatment of ACL injuries by Beynnon et al[1] concluded that "it appears that the time interval from ACL injury to reconstruction is not as important as the condition of the knee at the time of surgery." Despite this, a recent study[2] concluded that primary ACL reconstruction surgery should be carried out within 1 year after injury to minimize the risk of meniscal tears and degenerative changes.

The present study is based on data from the Norwegian Knee Ligament Registry (NKLR), established in 2004,[4] with the aim to study the association between timing of ACL reconstruction and the risk of having meniscal tears and cartilage lesions in the ACL-injured knee.

MATERIALS AND METHODS

We reviewed all patients registered in the NKLR who had undergone primary ACL reconstruction surgery in Norway between June 7, 2004, and December 31, 2006.

The NKLR is a cohort designed to collect information prospectively on all cases of cruciate ligament reconstruction surgery performed in Norway. Because of logistic and diagnostic issues, patients not receiving surgical treatment for their ACL injuries are currently not included in the NKLR cohort.[4] Thus, no control group is included in this study.

The NKLR makes use of both objective and subjective end points. The hard end points are revision surgery after cruciate ligament surgery and insertion of a total knee replacement. The NKLR includes routine follow-ups on all patients at 2, 5, and 10 years postoperatively using the Knee Injury and Osteoarthritis Outcome Score (KOOS)[9] as a soft end point. The KOOS form is also completed preoperatively by the patients.

The NKLR has a compliance rate of 97% with respect to all reconstructive ACL surgeries in Norway. Further details about the registry are described in Granan et al (2008).[4]

From the NKLR, we obtained preoperative details about age at time of surgery, sex, date of injury and date of surgery, location of any associated meniscal tears, and location and grading (according to the International Cartilage Repair Society [ICRS])[7] of any associated cartilage lesions.

The patients were divided into 3 different age groups according to age at time of surgery: children, 16 years and younger; young adults, 17 to 40 years; and older adults, 41 years and older. Children are expected to differ from adults due to skeletal immaturity, whereas older adults are expected to differ from younger adults due to the natural process of degenerative changes in the aging knee.

Logistic regression analyses were used to estimate the relationship between time from injury until primary reconstructive ACL surgery and the risk of meniscal tears or cartilage lesions. The risk for cartilage lesion (1) or not

TABLE 1
Patient Characteristics and Injury Distribution at Time of Surgery

	Age Group, y					
	<17 (n = 391)		17-40 (n = 2616)		>40 (n = 468)	
Characteristic	n	%	n	%	n	%
Males	111	28	1583	61	283	61
Median age (range)	15 (12-16)		26 (17-40)		45 (41-67)	
Previous knee surgery	50	13	621	24	166	36
Current other knee ligament injury[a]	15	4	150	6	45	10
Type of meniscal tear						
No tear	198	51	1414	54	225	48
Medial	93	24	486	19	135	29
Lateral	65	17	416	16	40	9
Both	20	5	207	8	47	10
Location unknown	15	4	93	4	21	4
ICRS grading[b]						
No cartilage injury	328	84	1972	75	268	57
Grade 1	30	8	221	8	42	9
Grade 2	22	6	252	10	78	17
Grade 3	6	2	119	5	56	12
Grade 4	3	1	42	2	20	4
Grading unknown	2	1	10	<0.5	4	1

[a]Medial collateral ligament, lateral collateral ligament, or posterolateral corner injury.
[b]ICRS, International Cartilage Repair Society. Grade 1, nearly normal: superficial lesions, soft indentation, and/or superficial fissures and cracks. Grade 2, abnormal: lesions extending down to <50% of cartilage depth. Grade 3, severely abnormal: cartilage defects extending down >50% of cartilage depth as well as down to calcified layer. Grade 4, severely abnormal: osteochondral injuries, lesions extending just through the subchondral bone plate, or deeper defects down into trabecular bone.

(0), as well as for meniscal tears (1) or not (0), was studied using the logistic regression models. First, unadjusted analyses were performed to identify potential confounders. The relationships between time from injury until surgery and risk factors and between potential confounders and the risk of cartilage lesions or meniscal tears were calculated. Risk factors with a significant relationship (using $P < .20$) with time from injury until surgery and potential confounders with a significant relationship (using $P < .20$) to either cartilage lesion or meniscal tear prevalence were used as adjustment factors for potential confounding in the adjusted logistic regression models. The factors identified were age, sex, previous knee joint surgery (ie, surgery to medial collateral ligament [MCL], lateral collateral ligament [LCL], posterolateral corner [PLC], cartilage, medial meniscus, lateral meniscus, or other specified structure), current knee ligament injury (ie, LCL, MCL, and/or PLC), meniscal tears, and cartilage lesions. The analyses were stratified by age groups and adjusted for time to surgery, sex, age (as a continuous variable), previous knee joint surgery, current knee ligament injury, and the presence of cartilage lesions or meniscal tears at the time of surgery.

Unadjusted analysis was performed to estimate the mean difference in months from injury until surgery between risk factors and confounding factors. P values less than .05 were considered to be statistically significant. Odds ratios are presented with 95% confidence intervals (CIs).

All statistical analyses were performed using SPSS for Windows, version 15.0 (SPSS, Chicago, Illinois).

RESULTS

A total of 4212 procedures were registered in the NKLR, and 3699 of these were primary ACL reconstructions (Figure 1). After excluding patients with previous or current posterior cruciate ligament injury or surgery and cases in which the date of injury was unknown, we were left with 3475 knees. The median time from injury to surgery was 7 months (range, 9 days to 482 months). Of the 3475 cases identified, there were 1977 (57%) male and 1498 (43%) female patients, with a median age of 27 years (range, 12-67 years).

The number of patients, sex, age, distribution of current and previous surgeries, and distribution of meniscal and cartilage injuries across age groups are shown in Table 1. Of 246 cases with at least 1 cartilage lesion grade 3 or 4, 120 cases (49%) had 1 or more lesions larger than 2 cm^2.

Among children, we were not able to detect a significant effect of time elapsed from injury until surgery on the prevalence of either cartilage lesions (Table 2) or meniscal tears (Table 3). The presence of cartilage lesions led to increased odds for the presence of meniscal tears (Table 3). Conversely, the odds for cartilage lesions were also increased in the presence of meniscal tears (Table 2). Within this age

TABLE 2
Logistic Regression Analysis of Cartilage Lesions[a]

	Age Group, y					
	<17		17-40		>40	
Variable	Coefficient of Regression	Odds Ratio (95% CI)	Coefficient of Regression	Odds Ratio (95% CI)	Coefficient of Regression	Odds Ratio (95% CI)
Previous surgery						
No		1[b]		1[b]		1[b]
Yes	0.620	1.86 (0.88-3.94)	0.438	1.55 (1.25-1.92)	0.706	2.03 (1.32-3.11)
Current injury						
No		1[b]		1[b]		1[b]
Yes	0.701	2.02 (0.59-6.89)	0.785	2.19 (1.53-3.13)	0.471	1.60 (0.83-3.08)
Meniscal tears						
No		1[b]		1[b]		1[b]
Yes	0.701	2.02 (1.15-3.54)	0.632	1.88 (1.56-2.27)	0.496	1.64 (1.10-2.46)
Age	0.167	1.18 (0.87-1.62)	0.030	1.03 (1.02-1.05)	–0.001	1.00 (0.96-1.04)
Sex						
Male		1[b]		1[b]		1[b]
Female	0.047	1.05 (0.56-1.96)	–0.122	0.89 (0.73-1.07)	–0.207	0.81 (0.54-1.23)
Time to surgery, mo	–0.015	0.99 (0.95-1.02)	0.006	1.006 (1.003-1.008)	0.007	1.007 (1.004-1.010)
Constant	–4.595		–2.507		–1.083	

[a]CI, confidence interval.
[b]Reference category to which the other categories are compared.

TABLE 3
Logistic Regression Analysis of Meniscal Tears[a]

	Age Group, y					
	<17		17-40		>40	
Variable	Coefficient of Regression	Odds Ratio (95% CI)	Coefficient of Regression	Odds Ratio (95% CI)	Coefficient of Regression	Odds Ratio (95% CI)
Previous surgery						
No		1[b]		1[b]		1[b]
Yes	0.080	1.08 (0.58- 2.01)	–0.220	0.80 (0.66-0.97)	–0.969	0.38 (0.25-0.58)
Current injury						
No		1[b]		1[b]		1[b]
Yes	–1.099	0.33 (0.10-1.09)	–0.264	0.77 (0.55-1.08)	–0.601	0.55 (0.28-1.06)
Cartilage lesions						
No		1[b]		1[b]		1[b]
Yes	0.705	2.02 (1.15-3.55)	0.631	1.88 (1.56-2.26)	0.498	1.65 (1.10-2.47)
Age	–0.235	0.79 (0.63-0.99)	–0.016	0.98 (0.97-1.00)	–0.029	0.97 (0.93-1.01)
Sex						
Male		1[b]		1[b]		1[b]
Female	–0.002	1.00 (0.63-1.58)	–0.434	0.65 (0.55-0.76)	–0.618	0.54 (0.36-0.80)
Time to surgery, mo	0.001	1.001 (0.982-1.022)	0.004	1.004 (1.002-1.006)	0.002	1.002 (0.999-1.004)
Constant	3.458		0.275		1.756	

[a]CI, confidence interval.
[b]Reference category to which the other categories are compared.

group, we also found that the prevalence of meniscal tears decreased with age.

In the young adult group, there were several factors that influenced the prevalence of cartilage and meniscal lesions. An increase in odds with time to surgery was seen for both types of lesions. The odds for a cartilage lesion increased by 1.006 (95% CI, 1.003-1.008) for each month that elapsed from the injury date until the surgery date. The same applied to meniscal tears, where we observed a monthly increase in odds by 1.004 (95% CI, 1.002-1.006).

TABLE 4
Mean Difference in Months From Injury Until Surgery Between Risk Factors and Confounding Factors

Variable	Mean Difference	95% Confidence Interval
Previous surgery		
No	–22	–26 to –19
Yes	0[a]	
Current injury		
No	13	6 to 19
Yes	0[a]	
Cartilage lesions		
No	–16	–19 to –13
Yes	0[a]	
Meniscal tears		
No	–4	–7 to –1
Yes	0[a]	
Age groups, y		
<17	–33	–39 to –27
17-40	–22	–27 to –18
>40	0[a]	
Sex		
Male	–5	–8 to –2
Female	0[a]	

[a]Reference category to which the other categories are compared.

Previous surgery increased the odds for having a cartilage lesion (Table 2), whereas it decreased the odds for having a meniscal tear (Table 3). A current injury of the MCL, LCL, and/or PLC was associated with increased odds for cartilage lesions (Table 2). The presence of a meniscal tear increased the odds for cartilage lesions (Table 2) and vice versa (Table 3). The older the young adults were, the higher the odds were for a cartilage lesion (Table 2), whereas the odds for having a meniscal tear decreased with increasing age (Table 3). Being female reduced the odds of having a meniscal tear (Table 3), whereas there was no gender effect on the risk for cartilage lesions (Table 2).

In the older adult group, the odds for having a cartilage lesion increased by 1.007 (95% CI, 1.004-1.010) for each month that elapsed from the injury date until the surgery date, whereas there was no association between time until surgery and the odds for meniscal tears. The presence of previous surgery to knee ligaments, cartilage, and/or menisci increased the odds for having cartilage lesions (Table 2), whereas the odds for having meniscal tears were decreased (Table 3). An additional meniscal tear increased the odds for a cartilage lesion (Table 2) and vice versa (Table 3). Being female reduced the odds of having a meniscal tear (Table 3), but there was no effect on the odds for cartilage injuries.

Table 4 displays the mean differences in months from injury until surgery between sexes, previous knee joint surgery to the index knee, current knee ligament injury other than cruciate ligament injuries, patient age groups, and the presence of either meniscal tears or cartilage lesions.

DISCUSSION

The main findings of this study were that the odds for a cartilage lesion in the adult knee increased by nearly 1% for each month that elapsed from the injury date until the surgery date and that cartilage lesions were nearly twice as frequent if there were a meniscal tear and vice versa.

The main strength of our study is the large number of patients included. Another strong point is that the patients originated from a national and general population of ACL-injured patients. The main weakness of this study is that all details regarding the patients are solely based on the individual orthopaedic surgeons reporting to NKLR. The collected data regarding the condition of the cartilage and menisci are based on the arthroscopic findings of many different surgeons, and their estimations of cartilage injury location, size, and depth may vary. One level III study regarding ICRS scoring has been published suggesting that this system is valid for the assessment of cartilage repair and has been found to have good interpersonal value and be repeatable and, as such, is regarded as a precise tool in the evaluation of cartilage repair.[9]

In the present study, patients who had asymptomatic cartilage or meniscal injury before their ACL injuries represent a potential source of bias. One cannot be entirely sure that the cartilage and meniscal tears reported to the NKLR had been sustained at or after the index ligament injury. Another potential limitation is that patients who expect instability to be a problem or cannot afford instability problems (eg, manual laborers, professional athletes, those who perform pivoting leisure-time activities) are more likely to undergo surgery early in contrast to patients who receive surgery after having experienced at least 1 episode of instability or giving way of the knee. One might expect that older patients are more likely to try nonoperative treatment first and wait longer before undergoing surgery. This is an argument supported by the data presented in Table 4. In addition to this, previous data from Norway[5] have estimated that at least 50% of patients with ACL injuries are treated nonoperatively. On the other hand, it is also likely that as time goes by, the chance of having surgery increases if you sustain further injuries to the knee. Then again, surgeons do have different practice profiles. Some are in favor of early surgery, some are leaning toward surgery after a thorough rehabilitation period, and some are somewhere between these 2 practice profiles. The consequence of one, some, or all these aspects is that we might overestimate the importance of time as a risk factor for developing degenerative lesions. The registration of preoperative KOOS data might to some degree counterbalance these limitations. One could argue that trying to formalize and register the patients' reasons for delaying or undergoing reconstructive surgery would be a more desirable approach. The NKLR's steering committee is currently reviewing this issue.

There are 2 other important variables that might bias the results; unfortunately, they are not yet part of the NKLR's registration form. These are the patient's weight and activity level. Either one of these factors is considered to increase the incidence of cartilage lesions and/or meniscal

tears.[6,12,15] Both factors are under consideration by the NKLR's steering committee for inclusion in both the preoperative and postoperative patient assessments.

There are different opinions on whether reconstructive surgery will result in fewer degenerative changes in the ACL-deficient knee in the long run compared with nonoperative treatment. A recent article by Drogset et al[3] suggested that early surgical intervention would be beneficial because the knees at an early stage had far less cartilage damage than did knees with late surgery. Our results confirm this. A recent study[2] based on review of 183 cases concluded that primary ACL reconstruction surgery should be carried out within 12 months of injury to minimize the risk of meniscal tears and degenerative changes. In this study, presence and type of meniscal tear and type of degenerative change were recorded. The incidence of meniscal tears and degenerative change was assessed and related to the timing from injury to surgery. The patients were divided into an early group (surgery within 12 months of injury) and a late group (surgery more than 12 months from injury). Incidence of meniscal tears was significantly higher in patients undergoing reconstruction late compared with those in the early group (71% vs 42%).

Six percent of the patients with ACL injuries had additional ligament injuries. The presence of these additional injuries might be owing to more severe trauma or more instability and as such explain the reason for these patients receiving surgery 1 year earlier than did those without other ligament injuries. Whereas Beynnon et al[1] found that ACL injuries are more prevalent among female athletes than male athletes, more ACL reconstructions are performed on male athletes because more males participate in at-risk sports, such as team handball and soccer.

Regarding the children's age group, the distribution in time from injury to surgery in relation to type of meniscal tear and ICRS grading does reflect relatively fewer findings (data not shown) in the children who received surgery in the latter end of the time scale. This probably reflects 2 tendencies among Norwegian orthopaedic surgeons. First, the most severely injured knees are operated on fairly soon. And second, in Norway, ACL reconstruction in children seldom occurs before the age of 14 years. This leads to a long time period between injury and stabilizing surgery for children with an early ACL tear. The protocol for these children consists of activity modification and use of a brace when performing knee-demanding activities. These data indicate that this approach does not lead to high incidence of meniscal tears and/or cartilage lesions.[13]

The change in odds for a single patient who chooses to have late surgery, the accumulated odds of 1 specific patient at a given time, and the difference in odds between 2 patients may be calculated using the coefficient of regression presented in Tables 2 and 3. This is illustrated in the following 2 examples (described in more detail in the appendix, available online at http://ajs.sagepub.com/supplemental/): a 34-year-old patient with previous surgery to the index knee has an additional ligament injury and a meniscal tear. The increase in odds for having a cartilage lesion for a 2-year difference in the timing of surgery is 1.2. This illustrates that the statistical risk for cartilage lesions increases by 20% for a 2-year difference in the timing of surgery for patients belonging to the patient group of young adults with the same risk profile as presented in this example. This example only calculates the additional increased odds for having cartilage lesions if surgery is 2 years later and does not include the increased risk at time zero (ie, previous surgery to the index knee, additional ligament injury, and a meniscal tear giving a baseline odds of 1.3).

Another example illustrates the difference in odds between 2 patients. Patient A is a 17-year-old male with no previous surgery to the index knee, no additional ligament injuries, and no damaged menisci. Patient B is twice as old (34 years), is the same sex, has previous surgery to the index knee, and has an additional ligament injury and a meniscal tear. These risk profiles will give patient B a 10.6 times increased odds for having cartilage lesions in relation to patient A, which gives an increased odds of 960%, based on the logistic regression model.

On the basis of our results on adults, early surgery may be recommended. However, it is important to remember that many surgeons consider these patients to benefit from preoperative rehabilitation[8,16] and that some patients may do well without surgery if they do not participate in high-risk activities.[1,11] If sufficient improvement is not achieved within reasonable time, surgery should be considered. A reasonable cutoff can be calculated for each patient based on Tables 2 and 3.

Church and Keating[2] specifically attempted to relate the development of degenerative changes in the knee to the timing of primary reconstruction surgery of the ACL. Our findings do concur with their main conclusions. To extend their findings, we have tried to provide both the physicians and the physical therapists with a new and more individualized tool to help in the decision making.

In conclusion, the odds for a cartilage lesion in the adult knee increased by nearly 1% for each month that elapsed from the injury date until the surgery date, and the presence of cartilage lesions was associated with a nearly 2-fold increase in the risk of having meniscal tears, and vice versa, independent of patient age. Our data suggest that early surgery is associated with fewer meniscal tears and cartilage injuries.

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Both examples make use of the coefficients of regression (young adults) drawn from table 2.

Example 1

A 34-year old (0.030 * 34) male with previous surgery to the index knee (0.438) has an additional ligament injury (0.785) and a meniscal tear (0.632). The increase in odds for having a cartilage lesion for a two-year (= 24 months) difference in the timing of surgery (0.006 * 24) may be calculated as follows. -2.507 is the constant for the young adults.

When inserting the values for these variables at a given time after injury

$$\text{logit}(pA_0) = -2.507 + 0.030 * 34 + 0.438 + 0.785 + 0.632$$

and two years later (the patient is now 36 years: 0.030 * 36, instead of 0.030 * 34)

$$\text{logit}(pA_1) = -2.507 + 0.030 * 36 + 0.438 + 0.785 + 0.632 + 0.006 * 24$$

The difference logit (pA_1) – logit (pA_0) is

$$\text{logit}(pA_1) - \text{logit}(pA_0) = 0.030 * (36 - 34) + 0.006 * 24 = 0.204$$

which gives an odds ratio of

$$\exp(0.204) = 1.2.$$

To simplify the calculations the expression exp(0.204) can be exchanged with $2.718^{0.204}$. These calculations illustrate that that the risk for cartilage lesions increases by 20 % for a two-year difference in the timing of surgery. This example only calculates the additional increased odds for having cartilage lesions if surgery is two years later and do not include the increased risk at time 0 (i.e. previous surgery to the index knee, additional ligament injury and a meniscal tear giving a baseline odds of 1.3). This example does also illustrate how to calculate a reasonable cut off.

Example 2

Patient A is a 17 year old male (0.030 * 17) with no previous surgery to the index knee (0); no additional ligament injuries (0); and no damaged menisci (0). Patient B is twice as old (34 years; 0.030 * 34), same sex, with previous surgery to the index knee (0.438), and has an additional ligament injury (0.785) and a meniscal tear (0.632).

When inserting the values for these variables we will get for patient A

$$\text{logit}(pA) = -2.507 + 0.030 * 17 + 0 + 0 + 0$$

and for patient B

$$\text{logit}(pB) = -2.507 + 0.030 * 34 + 0.438 + 0.785 + 0.632$$

The difference logit (pB) – logit (pA) is

$$\text{logit}(pB) - \text{logit}(pA) = 0.030 * (34 - 17) + 0.438 + 0.785 + 0.632 = 2.365$$

which gives an odds ratio of

exp (2.365) = 10.6.

These calculations will give patient B a 10.6 times increased odds for having cartilage lesions in relation to patient A (i.e. an increased risk of 960 %).

Paper III

The Scandinavian ACL registries 2004-2007: baseline epidemiology.

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Abstract

Background and purpose: No prospective surveillance systems have been available for monitoring the outcome of cruciate ligament surgery in Scandinavia (Denmark, Norway and Sweden). The present paper describes the Scandinavian ACL registries with their main function, similarities and preliminary baseline results.

Methods: The Scandinavian registries were established in 2004 (Norway) and 2005 (Denmark and Sweden). The Danish and Swedish registries were developed based on the Norwegian registry, and do not differ in any decisive way. In Denmark all hospitals and clinics are legally bound to report to an approved national database. In Norway and Sweden the registries are based on surgeons voluntarily reporting.

Results: The annual incidence of primary ACL reconstructions is higher in Denmark than in Norway, except in females younger than 20 years. A similar approach to the patients exists among the Scandinavian surgeons. Variations do however exist regarding choice of grafts, implants, and treatment of simultaneous meniscal and cartilage injuries; the proportion of ACL reconstructions performed as outpatient surgery; and the use of prophylactic anticoagulation. The preoperative KOOS scores do not clinically significantly differ between the Scandinavian registries, except for Denmark reporting more symptoms both pre- and postoperatively.

Interpretation: The Scandinavian national ACL registries will generate new data about ACL reconstructions. They will contribute important knowledge regarding ACL epidemiology. They will be the only source for data on performance of a wide range of different implants and techniques. They will hopefully have an impact on the selection of methods for ACL reconstructions in Scandinavia and elsewhere.

Introduction

Scandinavian national arthroplasty registries have over the last two decades generated important knowledge and served as an important quality control tool. Until Norway started the world's first national knee ligament registry in 2004 there were no prospective national surveillance systems to monitor the outcome of knee ligament surgery (Granan et al. 2008).

We describe the 3 Scandinavian – Danish, Norwegian and Swedish – knee ligament registries with their main function and similarities. Furthermore preliminary baseline results are presented from the start of the registries until late 2007 for primary ACL reconstructions.

Patients and methods

The Scandinavian registries were established in June 2004 (Norway), January 2005 (Sweden) and July 2005 (Denmark), the latter were developed based on the Norwegian registry. The registries do not differ in any decisive way. Details on the Norwegian ACL registry have previously been described by Granan et al. (2008).

The Norwegian and Swedish registries are based on surgeons voluntarily reporting to the registries. In Denmark a law passed in June 2006 made it compulsory for all public and private hospitals and clinics to report to the approved national, clinical databases. Reporting to the databases in Denmark and Sweden is organized through a secured internet portal, thus minimizing the costs of daily running. In Norway the registry relies on paper based reporting, mainly due to the close cooperation with the Norwegian Arthroplasty Register (NAR) which makes use of an identical system.

In Denmark 90 % of the orthopedic departments have been contributing to the registry with an average compliance of 85 % of the performed primary ACL reconstructions. In Norway all hospitals performing ACL surgeries have contributed with a total compliance of 97 %. In

Sweden some of the smaller hospitals with small volumes of ACL surgery have not been included in the registry, yet still more than 71% of the hospitals have contributed to the registry.

Follow up with KOOS forms are carried out by all 3 registries. In Denmark these follow ups are done at 1, 5 and 10 years postoperatively; In Norway at 2, 5 and 10 years postoperatively; and in Sweden at 1, 2, 5 and 10 years postoperatively.

All registries provide annual reports, national as well as for the individual hospitals. Sweden also offers an on-line database where clinics can analyze their own statistics at any time. The Danish database is managed by a special university center which manages all Danish national orthopedic databases. In Norway the technical responsibility is with the Helse Vest IKT AS, which manages all Norwegian national orthopedic databases. In Sweden the Capio Artro Clinic in Stockholm is responsible for the registry on a daily basis.

For this present study on this cohort, data regarding common and comparable variables (activities causing injury; age at injury and surgery; choice of graft; duration of surgery; frequency of cartilage and meniscal injuries, meniscal resections, and cartilage treatments; number of reconstructions and hospitals; graft fixation devices; outpatient surgery, pre operative and post operative KOOS; prophylactic antibiotics and anticoagulation; sex; and time to surgery) in relation to primary ACL reconstructions were extracted.

Ethics

In Norway the participation is voluntary, and all patients are asked to sign an informed consent form before surgery. The consent form contains information about the Norwegian ACL registry, the type of information that is recorded, data protection, the procedure for follow ups and informs the patient that he or she may be invited to participate in research projects at a later stage. The registration forms are signed by the surgeons, but they are not

possible to trace in the registry database since the surgeon's identity is not recorded, due to a mutual agreement among the Norwegian orthopaedic registries. For follow ups the patients are identified by their unique social security number (including date of birth), which is assigned to all Norwegian residents. The social security number is used to link the Knee injury and Osteoarthritis Outcome Score (KOOS) and registration forms, and to update the registry annually with data about knee arthroplasties from NAR, and death and emigration data before obtaining data files for analysis. The Norwegian ACL registry has been approved by the Norwegian Data Inspectorate as an expansion of the NAR concession. In Denmark and Sweden, no consent is necessary for national clinical databases. In Denmark and Sweden the social security number is used to access patients to the database and for identifying data.

Results

The total number of reported primary ACL reconstructions was 4972 in Denmark, 5329 in Norway, and 7331 in Sweden. The distributions of male patients were 57 % in Norway, 58 % in Sweden, and 60 % in Denmark. Of the Danish patients 1939 (39%) had simultaneous meniscal injuries and 825 (17%) had cartilage injuries. In the Norwegian patients the corresponding figures were 2914 (55%) and 1456 (27%), and in Sweden 2536 (35%) and 2001 (27%). The median age of the patients at the time of injury varied between 23 (Sweden) and 27 years (Denmark), while the median age at the time of surgery varied between 25 (Sweden) and 30 years (Denmark). The median time, in months from injury to surgery varied between 7 (Norway) and 10 (Sweden). At surgery the median duration varied between 68 min (Denmark) and 71 min (Sweden). Outpatient surgery was performed in 38 % of the cases in Norway, 56 % in Sweden and 79 % in Denmark. In all countries 99 % of the patients received prophylactic antibiotics, while the use of prophylactic anticoagulation varied between 17 % in Denmark and 78 % in Norway. These surgeries were conducted on 37 hospitals in Denmark,

52 hospitals in Sweden, and 60 hospitals in Norway. Hamstring autografts were the most frequently used graft in all of Scandinavia (Norway 61 %; Denmark 71 %; Sweden 86 %). Most often soccer was the cause of injury (Norway 40 %; Sweden 41 %; Denmark 50 %) (Table 1).

The KOOS data, both preoperatively and postoperatively, displayed no national clinical significant differences in any of the subscales, except for the poorer symptom scores in the Danish patients (Table 2). The Danish KOOS data is based on 50 % of the patients in the registry, while the Norwegian data constitutes 88 % of the registered patient population.

The annual incidence of primary ACL reconstructions in Norway was 34 per 100,000 citizens (Granan et al. 2008), while in Denmark the incidence was 38/100,000 (Lind et al. 2008), and in Sweden 32/100,000. On the other hand the real population at risk – that is 16-39 year age group – had an incidence of 85 primary ACL reconstructions per 100,000 citizens in Norway (Granan et al. 2008), while the Danish incidence was 91/100,000 for the 15-39 year age group (Lind et al. 2008), and the Swedish incidence was 71/100,000 for the 20-39 year age group. The annual incidence of primary ACL reconstructions for the different age groups in Denmark, Norway and Sweden are displayed in table 3.

Discussion

In general the registries provided detailed epidemiological data. Based on conservative estimates the Scandinavian ACL registries are expected to generate an annual average of 2500 patients in each of the Danish and Swedish registries, and 1600 patients in the Norwegian registry. After 5 years more than 30,000 cases will be in the registries yielding data such as the revision rates; KOOS; and the outcome related to various techniques and used implants.

It is also important to emphasize what the registries will *not* be able to demonstrate. There is no radiographical follow-up of the ACL reconstructed patients. Consequently, data regarding

the development of radiographically verified osteoarthritis will not be obtainable. The choice of not doing radiographic follow-ups is due to both financial restraints and the intention to not put additional demands on the hospitals that are beyond their own follow-up routines. More advanced investigations (e.g. gait analysis and muscle strength) are also omitted, due to the same arguments.

It is the registries' main intention to contribute to quality control and improvement of the surgical cruciate ligament procedures. This may be done through establishing evidence based national guidelines and protocols for surgical procedures and rehabilitation. To understand the importance of reported failures, we need to know the actual number of reconstruction and revision surgeries that are performed. Nordic arthroplasty registries have previously provided accurate data of sufficient quality. The Norwegian ACL registry has calculated that if 14 patients with one specific fixation device fail, this may be considered a failure of that specific device (Granan et al. 2008). This will enable the registries to give early warnings on poor procedures and devices, and identify prognostic factors etc (Granan et al. 2008).

The registries must provide information for the orthopedic community at regular intervals on the outcomes of surgical treatment of the cruciate ligaments with different methods. The hard endpoints are clear and unequivocal, i.e. revision reconstruction and total knee replacement. Causality of failure may not be sufficiently and accurately documented in the registries, but it will provide information as to where there may be potential problems and direct future analysis and studies toward these areas. Since the registries will provide real time information and thus can be analyzed on an ongoing basis, they have the potential to reveal problems long before they would be reported by traditional methods (e.g. RCTs). This will undoubtedly benefit all interested parties, not at least the patients.

An important limitation in these registries is bias due to limitation in follow-ups. From the Norwegian registry we know that baseline compliance is high both in respect to registration

forms (97 %) and KOOS forms (88 %). Mandatory reporting has been instituted in Denmark. This might be the most important condition to obtain a high and sustainable compliance. Due to the Scandinavian unique social security numbers it is easy to reach every patient, and thus increase the response rate in the follow-ups.

There still are issues where the Scandinavian registries have no solutions. Due to logistic and diagnostic issues, patients not receiving surgical treatment for their ACL injury are currently not included in the Scandinavian registries. Thus, no data on the outcome of non-operatively treated ACL injuries are obtained. Another limitation in these registries is the use of revision as a primary end point. This is suboptimal since an unknown number of patients accept to live with an inferior clinical outcome to avoid more surgery. However, if they undergo surgery for debridement or arthroscopic surgery for other indications, they will be detected in the registry. Knee arthroplasty has limitations as an endpoint because it can take several decades before a patient with a poorly functioning knee is accepted as a knee arthroplasty candidate. Not all patients with ACL insufficiencies develop osteoarthritis to a degree where knee arthroplasty is indicated (Lohmander et al. 2007).

The registration of potential risk factors other than type of surgical procedure may be subject to selection bias. The data items recorded are a minimal set suited for a paper-based or web-based reporting system, not to exceed one page. As such there has to be a careful, ongoing selection of what is expected to be the most important risk factors. Thus, there is no way of knowing the influence of the omitted variables. Finally there might be limitations due to differences between Scandinavia and other countries in respect of indications for surgery and patient success criteria.

Prospective national registries have several advantages. Inclusion of cases from an entire nation generates a high volume of data. This in turn, will lead to the possibilities of drawing early decisive conclusions. Another advantage is due to the nature of cohort studies, an

ongoing accumulation of short term and long term follow-up data. Finally there is the advantage of monitoring development, implementation and evolution of new – and old – techniques, implants, prophylactic medications and so forth. Although RCTs are the gold standard in research methods and are immensely valuable for detailed testing, they are insufficient when assessing techniques. A RCT aiming to demonstrate a 5 % difference in revision rates after ACL surgery would need nearly 500 patients in each group, far more than usually included in a typical RCT in knee ligament surgery.

Entirely web-based ACL registries are possible to develop – as demonstrated by the Danish and Swedish registries – and are accessible and cost effective. Some restraints exist due to various countries national legislation and infrastructure. Ultimately an emerging international cooperation is expected to increase quality, open barriers and create an open minded international discussion about methods and results in primary ACL reconstructions.

The different annual numbers in the Scandinavian registries are due to the differences in the population sizes. Even though Norway is the smallest country it has the largest number of hospitals. The explanation is likely to be due to a scattered population in a relatively long and narrow country.

The data in Table 1 reflects the similar approach to the patients among the Scandinavian surgeons. Some cultural variations do, however exist: The Swedish and Danish surgeons prefer hamstring grafts to a much larger extent than the Norwegian surgeons. The reporting of cartilage injuries in Norway was the first few years infested with flaws and inconsistency. This might explain why Norwegian surgeons report more than 50 % as many cartilage injuries as their Danish colleagues, and surgically treat less cartilage injuries than the Danes. However, the Swedish data are identical to the Norwegian. On the other hand, Norway report substantially more meniscal injuries than Denmark and Sweden, but treat relatively fewer injuries. This probably reflects cultural and national attitudes. The variation in ACL

reconstructions performed as outpatient surgery probably reflects the variation in the Scandinavian structure of the health care systems. The large variation in use of prophylactic anticoagulation is of interest, however, postoperative trombo-embolic complications are not recorded.

In respect of choice of autograft and fixation, the implants used (data not shown) in more than 2/3 of the cases varied between 1 and 3 different implants in the different registries. This gives an overall total of 4 to 6 different implants when looking at various grafts and their different fixation sites. This variation in the Scandinavian countries might be due to personal preferences, skill of medical company sales team or local financial decisions, or more likely combinations of these factors. There are no clinically significant differences in any KOOS subscale either pre- or post-operatively among the Scandinavian countries. The only exception is that Danish patients report clinically significant poorer symptoms score than their Norwegian and Swedish counterparts, both pre-operatively and post-operatively. Furthermore, the Danish and Swedish baseline KOOS data reveal an unsatisfactory compliance rate, for unknown reasons. The baseline KOOS (Table 2) are the most comprehensive data set published to date, and should be regarded as the reference values for preoperative KOOS in ACL injured patients.

There are as yet no explanations to the large discrepancies among the Scandinavian incidence data (Table 3). These differences must be investigated more thoroughly in separate studies.

The Scandinavian national ACL registries will generate new data about ACL reconstructions. They will contribute to a better understanding of the ACL epidemiology. They will be the only source for data on performance of a wide range of different implants and techniques. They will influence the selection of methods for ACL reconstructions in both Scandinavia and hopefully other countries in the future.

Contributions of authors

LPG designed the study, analyzed the Norwegian data, wrote the manuscript, and is guarantor. LE participated in the design of the study and writing of the manuscript, and supervised the work of LPG. ML participated in the design and writing of the manuscript, and analyzed the Danish data. MF participated in the design and writing of the manuscript, and analyzed the Swedish data.

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275 Table 1. Variables in the registration forms reported to the Scandinavian ACL registries.

Characteristics	Variable	Denmark	Norway	Sweden
Primary ACL reconstructions	N	4972	5329	7331
	Annual average[b]	1886	1520	2444
Hospitals	Total	37	60	52
Age at surgery	Median (range)	30 (10-71)	27 (12-67)	25 (8-67)
Age at injury	Median (range)	27 (7-70)	25 (6-65)	23 (5-66)
Gender	Males	60%	57%	58%
Grafts	Hamstring	71%	61%	86%
	BPTB	22%	38%	14%
	Others	7%	< 1%	< 1%
Meniscal injuries	Total	1939 (39%)	2914 (55%)	2536 (35%)
	Resection	1591 (79%)	2002 (69%)	2007 (80%)
Cartilage injuries	Total	825 (17%)	1456 (27%)	2001 (27%)
	Treatment (%)	482 (55%)	293 (20%)	401 (20%)
Duration of surgery[a]	Median in minutes (range)	68 (30-210)	70 (10-240)	71 (14-330)
Time to surgery	Median in months (range)	9 (0-371)	7 (0-482)	10 (0-527)
Outpatient surgery		79%	38%	56%
Prophylactic antibiotics		99%	99%	99%
Prophylactic anticoagulation		17%	78%	41%
Most frequent activities causing injury		Soccer 50% Team Handball 20% Downhill skiing[c] 14%	Soccer 40% Team Handball 15% Downhill skiing[c] 13%	Soccer 41% Downhill skiing[c] 13% Floor ball 8%

276 na = not available
277 a = skin-to-skin time for isolated primary ACL reconstructions
278 b = figure is lower than expected average due to the inclusion of the very first months of the
279 individual registries' running time
280 c = alpine skiing, telemark skiing and snowboarding

281 Table 2. KOOS scores, preoperative and follow ups, in the Scandinavian ACL registries.

When	Subscale	Denmark	Norway	Sweden
Preoperative	Pain	72	78	76
	Symptoms	57	75	70
	Function in ADL	79	88	85
	Function in sport and recreation	40	40	43
	Knee related QOL	40	31	33
1 year post-op.	Pain	84	na	85
	Symptoms	61	na	78
	Function in ADL	90	na	92
	Function in sport and recreation	63	na	64
	Knee related QOL	60	na	60
2 years post-op.	Pain	na	89	86
	Symptoms	na	86	80
	Function in ADL	na	97	92
	Function in sport and recreation	na	70	66
	Knee related QOL	na	69	62

282 na = not available

283 Table 3. Annual incidence of primary ACL reconstructions per 100,000 citizens in
284 Scandinavia.

Age (years)	Females			Males		
	Denmark	Norway	Sweden	Denmark	Norway	Sweden
10-19	71	76	88	71	47	59
20-29	85	64	62	191	112	117
30-39	79	42	39	137	77	65
40-49	52	24	27	69	38	31
50-59	10	8	6	15	5	5
60-69	3	0.5	0.2	2	1	0.4

285 na = not available
286
287
288

Paper IV

Cross-cultural Comparison of Patients Undergoing ACL Reconstruction in the United States and Norway

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Abstract

Background: Data from large prospectively collected ACL cohorts are being utilized to address clinical questions regarding ACL injury demographics and outcomes of ACL reconstruction. These data are affected by patient and injury factors as well as surgical factors associated with the site of data collection. The aim of this paper is to compare primary ACL reconstruction data from patient cohorts in the United States and Norway, demonstrating the similarities and differences between two large cohorts.

Methods: Primary ACL reconstruction data from the Multicenter Orthopaedic Outcomes Network (MOON) in the United States and the Norwegian Knee Ligament Registry (NKLR) were compared to identify similarities and differences in patient demographics, activity at injury, preoperative Knee injury and Osteoarthritis Outcome Score (KOOS), time to reconstruction, intraarticular pathology, and graft choice.

Results: 713 patients from the MOON cohort were compared with 4928 patients from the NKLR. A higher percentage of males (NKLR 57%, MOON 52%; $p < 0.01$) and increased patient age (NKLR 27 years, MOON 23 years; $p < 0.001$) were noted in the NKLR population. The most common sports associated with injury in the MOON cohort were basketball (20%), soccer (17%), and American football (14%); while soccer (42%), handball (26%), and downhill skiing (10%) were most common in the NKLR. Median time to reconstruction was 2.4 (Interquartile range [IQR] 1.2 - 7.2) months in the MOON cohort and 7.9 (IQR 4.2 - 17.8) months in the NKLR cohort ($p < 0.001$). Both meniscal tears (MOON 65%, NKLR 48%; $p < 0.001$) and articular cartilage defects (MOON 46%, NKLR 26%; $p < 0.001$) were more common in the MOON cohort. Hamstring autografts (MOON 44%, NKLR 63%) and patellar tendon autografts (MOON 42%, NKLR 37%)

were commonly utilized in both cohorts. Allografts were much more frequently utilized in the MOON cohort (MOON 13%, NKLR 0.04%; $p < 0.001$).

Conclusions: Significant diversity in patient, injury, and surgical factors exist among large prospective cohorts collected in different locations. Surgeons should investigate and consider the characteristics of these cohorts when applying knowledge gleaned from these groups to their own patient populations.

Introduction

The anterior cruciate ligament (ACL) is the most frequently injured ligament in the knee and its subsequent reconstruction is a commonly performed orthopaedic procedure. The evolution from primary repair through an open arthrotomy to arthroscopically assisted ACL reconstruction has allowed clinically stable ligament reconstruction in most patients.[1, 2] The arthroscopic approach decreases trauma to the knee joint and minimizes scarring while modern accelerated rehabilitation techniques reliably restore the knee range of motion and quadriceps strength necessary for resumption of sporting activities.[3-6]

However, a multitude of issues surrounding ACL surgery and postoperative rehabilitation remain unresolved. Some issues can and should be addressed by conducting properly designed randomized controlled trials. However, large prospective longitudinal cohorts are increasingly utilized as the most practical study design for collecting clinically relevant outcome data and prognostic factors. This study design can track the incidence of ACL graft failure, provide information on postoperative activity level and patient oriented outcome scores, and identify prognostic factors associated with outcome data.

Prospective ACL reconstruction cohorts are ongoing in Norway and the United States to determine both prognosis and predictors of outcomes following ACL reconstruction. The Multicenter Orthopaedic Outcomes Network (MOON) was established in 2002 to determine the prognosis and predictors of ACL reconstruction outcomes.[7] Similarly, the Norwegian National Knee Ligament Registry (NKLR) was established in 2004 after review of evidence from the Scandinavian joint replacement registries indicated that a national knee ligament registry could be highly beneficial.[8-11] These cohorts have been

utilized in the publication of papers describing the incidence of reconstruction in the general population[12] and the prevalence of ACL graft failure following ACL reconstruction,[7] and are expected to provide data to address many other clinical questions in the future. A key question in the analysis and interpretation of outcomes from these two prospective databases is their applicability to geographically and culturally diverse populations. Different patient demographics, injury mechanisms, preoperative treatment algorithms, surgical techniques, and patient expectations make for markedly different patient populations throughout the world. Attempts to generalize results from one specific population to another could lead to inaccurate conclusions unless the similarities and clinically relevant differences are known.

The aim of this paper is to compare primary isolated ACL reconstruction data from the MOON cohort and NKLR, demonstrating the similarities and differences between these two populations on opposite sides of the Atlantic Ocean. We describe patient demographics, activity leading to injury, time from injury to reconstruction, preoperative Knee injury and Osteoarthritis Outcome Score (KOOS), meniscal and articular cartilage findings and treatments at reconstruction, and graft selection for reconstruction. We hypothesize that there are statistically and clinically relevant differences between the cohorts as well as important similarities that should be noted by surgeons attempting to extrapolate results from such databases to their own patients.

Materials and Methods

Prospective Data Collection in MOON and NKLR

The MOON group began enrolling all ACL reconstruction patients at seven academic medical centers in the United States in 2002. A prospective longitudinal cohort design was established to determine the prognosis and identify predictors of outcome. Preoperatively, subjects complete a 13-page form that included the mechanism of injury; time from injury to reconstruction; additional injuries before reconstruction; a series of validated patient-oriented outcome questionnaires including KOOS[13] - which includes the Western Ontario and McMaster Osteoarthritis Index (WOMAC),[14] Marx activity score,[15] SF-36,[16] and International Knee Documentation Committee (IKDC) score;[17] sports participation history; co-morbidities; demographics; and any ongoing therapies.[7, 18, 19] The surgeon completes a detailed examination under anesthesia including the contralateral knee and detailed operative assessment and treatment of meniscus and articular cartilage injuries using the standard modified Outerbridge score.[20] The details of ACL reconstruction technique and rehabilitation milestones are also recorded. MOON enrolls approximately 500 patients undergoing primary ACL reconstruction annually.

The NKLR is designed to collect information prospectively on all cases of cruciate ligament reconstruction in Norway. Data collected includes mechanism of injury, time since injury, intraarticular findings (meniscal and chondral pathology), method of ligament reconstruction, and treatment of any other pathology. Cartilage lesions are graded according to the International Cartilage Repair Society (ICRS).[21] The patients

are also asked to complete the KOOS form in advance of surgery. Approximately 1600 patients undergoing primary ACL reconstruction are enrolled annually.

Retrospective Data Collection for this Analysis

After approval was obtained from appropriate institutional review boards, data from both the MOON cohort and NKLR were accessed. Each prospectively collected database included information about patient demographics (age and sex), activity associated with injury, time from injury to reconstruction, preoperative KOOS scores, meniscal and articular cartilage findings and treatments at reconstruction, and graft choice for reconstruction. These data were compiled from two years of MOON data on all primary ACL reconstructions performed between January 1 and December 31, 2002, and between June 1, 2007 and May 31, 2008; and from three and one half years of NKLR data on all primary ACL reconstructions performed between June 7, 2004, and December 31, 2007.

Data Analysis

Pearson's chi-square test was utilized to compare the proportion of men and women and the incidence of meniscal pathology in each cohort. Nonparametric methods (Mann-Whitney U test) were utilized to compare patient age and time from injury to reconstruction between the two groups as the data did not fit a normal distribution. A score in each of the five KOOS subscales was calculated for each patient utilizing the KOOS scoring sheet as published online.[13] Mean and standard deviations for each subscale were calculated for all patients for whom data was available in the respective databases and compared using a t-test as the data fit a normal distribution.

Source of Funding

There was no outside funding for this study comparing primary isolated ACL reconstructions in the MOON and NKLR cohorts. The MOON group and NKLR have external funding sources as outlined in the acknowledgement section. These funding sources play no role in data collection or analysis.

Results

Demographics (Table 1)

During the data collection period, 950 ACL reconstructions were enrolled in the MOON cohort. Revision ACL reconstruction was performed in 132 patients (13.9%), leaving 818 primary ACL reconstructions. Concurrent PCL, MCL, LCL, or posterolateral corner injury was noted in 105 patients (12.8%) who were excluded, leaving 713 patients with an undergoing primary ACL reconstruction for this analysis. During the data collection period, 5720 ACL reconstructions were logged in the NKLR. Revision ACL reconstruction was performed in 391 patients (6.8%), leaving 5329 ACL reconstructions for analysis. Concurrent PCL, MCL, LCL, or posterolateral corner injury was noted in 401 patients (7.5%) who were excluded, leaving 4928 patients with an isolated ACL reconstruction for this analysis.

The median age at reconstruction in the MOON cohort was 23 years (Interquartile range [IQR], 17-35), while the median for patients in the NKLR population was 27 years (IQR, 19-36 years) (Mann-Whitney U test, $p < 0.001$). The MOON cohort included 371 male patients (52.0%) and the NKLR population included 2825 male patients (57.3%) (Chi squared, $p < 0.01$).

Activity Associated with Injury (Figure 1)

In the MOON cohort, ACL injuries were associated with a sport in 88.5% of those for whom an injury mechanism was known. The most frequent activities associated with ACL injury in the MOON cohort were basketball (19.8%), soccer (16.8%), American football (13.5%), skiing (6.73%), other sports injuries (19.4%), work injuries (2.67%), motor vehicle accidents (1.12%), and other non-sport activities (6.03%). Injury mechanism was unknown in 3.22% of patients and not reported in 10.8% of patients.

In the NKLR, ACL injuries were associated with a sport in 86.7% of those for whom an injury mechanism was known. The most common activities associated with injury in the NKLR population were soccer (41.6%), handball (15.5%), downhill skiing (10.2%), other sports injuries (17.3%), work injuries (2.54%), motor vehicle accidents (1.85%), and other non-sport activities (8.28%). Injury mechanism was unknown in 1.12% of patients and not reported in 1.40% of patients.

Time from Injury to Reconstruction

A specific date of injury was known in 457 patients in the MOON cohort, allowing calculation of the median time from injury to reconstruction in 64.1% of patients. The median time from injury to reconstruction was 2.4 months (IQR, 1.2 – 7.2 months). A specific date of injury was known in 4672 patients in the NKLR population, allowing calculation of the median time to injury in 94.8% of patients. The median time from injury to reconstruction in the NKLR population was 7.9 months (IQR, 4.2-17.8 months) (Mann-Whitney U test, $p < 0.001$).

Pre-operative KOOS (Figure 2)

A preoperative KOOS was available for 643 patients (90.2%) in the MOON cohort and for 4182 patients (84.9%) in the NKLR population. Patients in both databases exhibited higher scores in the pain, other symptoms, and function in activity of daily living (ADL) subscales than in the function in sport and recreation (sport/rec) and knee related quality of life (QOL) subscales. Statistically significant differences between the two databases were noted in each KOOS subscale except knee related quality of life; however, only the difference in the "other symptoms" subscale exceeded the 8 points previously described as the minimum clinically significant difference.[22, 23] Differences in the other KOOS subscales are too small to be clinically significant.

Meniscal Pathology and Treatment (Figure 3)

In the MOON cohort, 461 patients (64.7%) had meniscal pathology. There were 273 medial tears and 319 lateral tears. In the NKLR population, 2386 patients (48.4%) had meniscal pathology. There were 1642 medial tears and 1235 lateral tears. The prevalence of meniscal pathology was significantly higher in the MOON cohort (Chi squared, $p < 0.001$).

In the MOON cohort, medial meniscal lesions were treated with resection (45.4%), repair (39.2%), trephination (2.2%), or observation (11.7%). Lateral meniscal lesions were treated with resection (60.8%), repair (14.1%), trephination (3.1%), or observation (21.0%). In the NKLR population, medial meniscal lesions were treated with resection (61.6%), repair (21.7%), trephination (1.0%), replacement (0.1%), or observation (10.0%). Lateral meniscal lesions were treated with resection (70.1%), repair (9.4%),

trephination (2.0%), or observation (13.0%). Treatment was not reported in 1.2% of patients in the MOON database and 5.5% of patients in the NKLR.

Resection was more frequently utilized in the NKLR population for all meniscal lesions, while repair and observation were more common in the MOON cohort (Chi square, $p < 0.05$). Trephination alone and replacement were rare in both databases.

Articular Cartilage Pathology and Treatment (Table 2)

In the MOON cohort, 326 patients (45.7%) had an articular cartilage injury of any type noted at reconstruction. Modified Outerbridge grade 3 or 4 lesions were noted in 133 patients (18.6%). Grade 3 and 4 lesions were most commonly located on the lateral tibial plateau, patella, and medial femoral condyle. In the NKLR population, 1302 patients (26.4%) were noted to have an articular cartilage injury of any type at reconstruction. ICRS grade 3 or 4 lesions were noted in 343 patients (6.9%). Grade 3 and 4 lesions were most commonly located on the medial and lateral femoral condyles. The incidence of articular cartilage pathology was significantly higher in the MOON cohort (Chi squared, $p < 0.001$).

In the MOON cohort, cartilage debridement (chondroplasty) was the most common treatment for grade 3 and 4 articular cartilage defects in all locations (64.8%). Observation alone was also common (24.9%). Microfracture was also utilized (14.4%), most commonly on the medial and lateral tibial plateaus and the medial femoral condyle. In the NKLR population, observation alone was most commonly utilized for grade 3 and 4 articular cartilage lesions in all locations (43.9%). Cartilage debridement (16.6%) and microfracture (15.1%) were frequently utilized, with microfracture utilized most

commonly on the medial and lateral femoral condyles and medial tibial plateau. In no cases in either the MOON or NKLR populations were mosaicplasty or autogenous chondrocyte implantation (ACI) utilized. Observation alone was generally utilized for grade 1 and 2 articular cartilage lesions in both cohorts.

Graft selection (Figure 4)

In the MOON cohort, the most common grafts were doubled semitendinosus ad gracilis autograft (309 patients, 43.6%) and patellar tendon autograft (300 patients, 42.4%). Other autografts accounted for four patients (0.56%) while allograft was utilized in 95 patients (13.4%). In the NKLR population, the most common grafts were doubled semitendinosus and gracilis autograft (2932 patients, 59.5%), patellar tendon autograft (1830 patients, 37.1%). Other autograft accounted for 148 patients (2.96%) while allograft was utilized in two patients (0.04%). The use of allograft was significantly higher in the MOON cohort than in the NKLR (Chi square, $p < 0.001$)

Soccer Subgroup Analysis (Figure 5)

Soccer was the only sport contributing a large number of patients in both populations. The MOON cohort contained 120 patients (16.8%) who injured their ACL playing soccer. They were 45.8% male and had a median age of 18 (IQR, 16-28). Meniscal pathology was noted in 74 soccer players (61.7%); articular cartilage pathology was identified in 42 soccer players (35.0%), and 13 patients (10.8%) were noted to have grade 3 or 4 articular cartilage defects. The NKLR population contained 2050 patients (41.6%) who injured their ACL playing soccer. They were 72.3% male and had a median age of 25 (IQR, 19-33). Meniscal pathology was noted in 1004 soccer players (49.0%); articular

cartilage pathology was identified in 503 soccer players (24.5%); and 144 patients (7.0%) were noted to have grade 3 or 4 articular cartilage defects.

Discussion

Prospective cohorts are the most practical clinical research design to define prognosis and identify modifiable predictors of outcomes. These two prospective cohorts are among the largest in the world to assess outcomes of ACL reconstruction, with multiple investigators collecting data on two continents.[12, 19, 24, 25] This wealth of data is available to physicians everywhere via a multitude of electronic sources, and knowledge gleaned from these data influences care of countless patients. A key question for physicians is how applicable these data are to their individual patient populations. Our comparison of demographic and treatment data from the MOON cohort with those from the NKLR draws attention to differences and similarities that can arise in data collected in different environments.

Demographics of patients undergoing ACL reconstruction can vary considerably. Our data demonstrate that patients injuring their ACL and undergoing reconstruction in Norway are on average older than patients in the MOON cohort in the United States. Similarly, a higher percentage of males were present in the NKLR population. These differences are likely due to differences in the geographic regions of data collection as well as differences in the manner of database collection. For example, in the United States a large percentage of athletes compete for high school and college sports teams, which do not exist in Norway where most athletes compete for club teams. Whereas many Americans cease playing team sports at the completion of school, many Norwegians continue to play for club teams long after finishing school, possibly

explaining the older demographics noted in the NKLR population. Gender differences may be explained by differences in sport participation rates among men and women in the two countries or differences in the frequency of utilization of injury prevention training protocols in female athletes. These protocols have been heavily researched and instituted in Norway, possibly decreasing the incidence of ACL tears in females athletes.[26] Additionally, as a national registry, the NKLR gathers a much broader cross section of surgeons than the MOON cohort, which is comprised exclusively of surgeons at seven academic institutions in the United States. The MOON patient group may not be a complete cross section of patients with ACL tears in the United States, as the majority of ACL reconstructions in the country are performed by surgeons in private practice. Similarly, healthcare system differences may introduce bias into which patients present to surgeons for reconstruction given that not all Americans have insurance and easy access to providers. Finally, treatment algorithms for ACL injuries differ between the two countries, with nonoperative management of ACL injuries attempted much more frequently in Norway. It has been estimated that 50% of ACL injuries in Norway are treated nonoperatively,[12, 27] while surveys of the centers participating in MOON data collection place the nonoperative treatment rate at 5 - 10%. This difference may in part be related to the increased patient age noted in the Norwegian data.

The activity associated with the injury to the ACL reflects the national popularity of various sports and activities and varies greatly between the two databases, as soccer was the only sport representing greater than 10% of injuries in both databases. However, the overall percentage of patients who injured themselves during a sporting activity was

similar. Greater than 85% of those who recalled a specific injury related it to sports in both groups.

Differences in the number of associated intraarticular injuries at the time of ACL reconstruction were also large. These differences are likely in part explained by different injury mechanisms associated with different sports. Different bone bruise patterns are known to occur in contact versus noncontact ACL injuries and the activity at the time of injury highly influences whether contact is involved in the injury.[28] Differences in the number of intraarticular injuries in the two databases may also be due to interrater differences in identifying and describing pathology. While the ICRS and modified Outerbridge cartilage grading systems have shown good interrater reliability, the determination of whether small meniscal fibrillation and degeneration amounts to a tear is quite subjective and subject to bias.[20, 29] These differences may also reflect intrinsic differences in data collection methods. MOON data are recorded by a small number of surgeons who all play a role in data collection and publication while NKLR data are recorded by numerous surgeons throughout the country, the majority of whom are only involved in data collection.

The poorer preoperative score on the “other symptoms” KOOS subscale noted in patients in the MOON database are not related to the increased additional intraarticular pathology in this group. Clinically significant difference remains even when comparing patients without intraarticular pathology other than ACL injury (data not shown). The difference may be related to differences in time from injury to KOOS in the two patient groups. The KOOS was obtained immediately preoperatively in both databases leading to a larger time between injury and KOOS in the NKLR group.

In order to eliminate differences in activity at injury as a confounding variable, we compared patients from both databases who were injured playing soccer. Differences were again noted between the two groups in amount of intraarticular pathology. However, further analysis reveals that differences still exist between the two groups. The overall differences in both age and gender between the two populations are even larger in the soccer subset. These demographic differences may explain differences in the rates of intraarticular injury between the two groups, or they may be related to other, unknown factors.

Differences in treatment philosophy greatly influence the timing of ACL reconstruction as well as the choice of ACL graft and treatment of associated intraarticular pathology. The median time from injury to reconstruction in the NKLR population was three times that in the MOON cohort. While some have hypothesized that increased time to reconstruction may increase the incidence of intraarticular pathology,[30-32] our data do not support this concept, as a greater incidence of intraarticular pathology was noted in the MOON cohort in spite of much earlier reconstruction. The fact that an increased percentage of meniscal tears in the NKLR group involved the medial meniscus may support the hypothesis, as the medial meniscus is known to be a restraint to anterior tibial translation in the case of ACL deficiency. However, as above, one must be wary of differences in patient demographics and injury mechanism when making this comparison. Similarly, the fact that 35% of patients in the MOON database were unable to identify a specific injury date may lead to an underestimation of median time to reconstruction in this group.

ACL graft choice was relatively similar between groups, with hamstring and patellar tendon autograft being the most common grafts in both. Allograft was much more frequently utilized in the MOON cohort at the time of data collection although the increased failure rates previously reported among younger patients will likely decrease that number in the future.[33, 34]

While treatment of meniscal tears was similar between the two databases the approaches to grade 3 and 4 articular cartilage defects were quite different. Surgeons in the MOON cohort were much more likely to report debriding cartilage while surgeons in the NKLR were more likely to treat lesions with observation. This difference may be real or due to differences in classification resulting from semantics – does one refer to a small amount of cartilage shaving as debridement or simply as observation? Surgeons utilized microfracture and abrasion techniques at similar rates in both databases.

This paper addresses differences in these databases related only to patient and injury characteristics and findings and techniques utilized at reconstruction. We have not reviewed any outcome data. However, multiple studies have documented the influence that intraarticular pathology at the time of reconstruction can have on outcome.[5, 35, 36] These data must therefore be carefully considered when reviewing outcome data from these and other such databases and applying it to other populations.

Conclusions

Important differences exist between the MOON and NKLR populations related to patient demographics, activity leading to injury, time to reconstruction, presence and treatment of intraarticular pathology, and graft selection. However, multiple similarities also exist,

including the almost identical percentage of injuries due to sport as well as similarities in preoperative KOOS scores, particularly the sport and activity function and knee related quality of life subscales. Similar differences potentially exist between other databases from various locations around the world. Surgeons should investigate the patient and surgical characteristics of such databases when applying knowledge gleaned from these groups to their own patient populations.

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Table 1: Demographics

Database	Inclusive Dates	Number of isolated primary ACL* reconstructions	Median Patient Age (IQR#)	Percent Male
Multicenter Orthopaedic Outcomes Network (MOON)	01.01.02 to 12.31.02 06.01.07 to 05.31.08	713	23 years (17-35 years)	52.0%
Norwegian National Knee Ligament Registry (NKLR)	06.07.04 to 12.31.07	4928	27 years (19-36 years)	57.3%

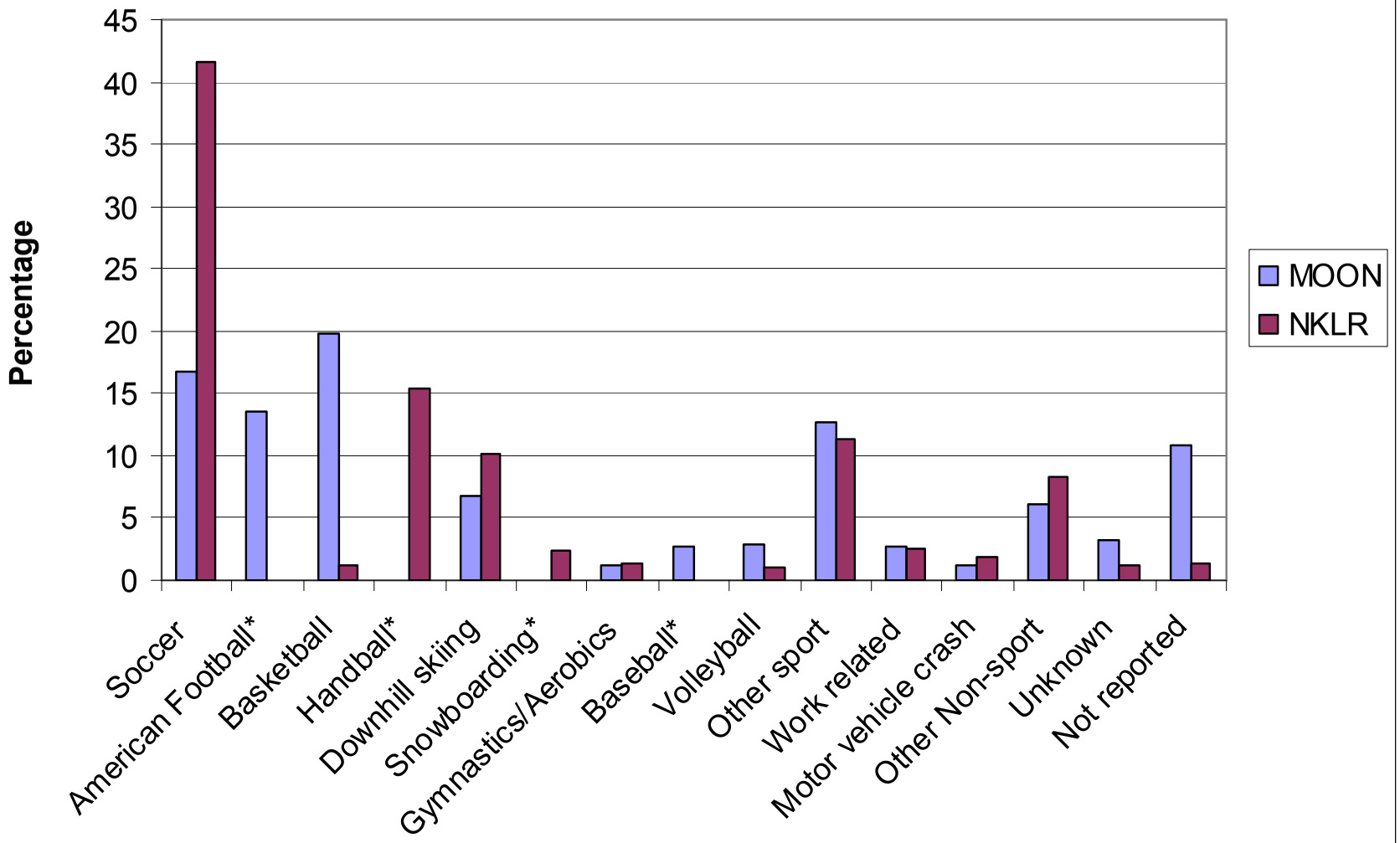
* ACL = Anterior Cruciate Ligament
# IQR = Interquartile range

Table 2: Treatment and Location of Grade 3 and 4 Articular Cartilage Defects.

Database	Lesions	Treatment / Location	Debridement	Microfracture	Periosteal flap	Observation	Other	Not Reported
MOON*	43 (6.03%)	Patella	37 (86.0%)	---	---	6 (14.0%)	---	---
NKLR#	38 (0.77%)		6 (15.8%)	1 (2.63%)	1 (2.63%)	19 (50.0%)	---	11 (28.9%)
MOON	18 (2.52%)	Trochlea	12 (66.7%)	2 (11.1%)	---	4 (22.2%)	---	---
NKLR	18 (0.37%)		---	1 (5.56%)	---	12 (66.7%)	---	5 (27.8%)
MOON	39 (5.47%)	Medial Femoral Condyle	21 (53.8%)	5 (12.8%)	---	12 (30.8%)	---	1 (2.56%)
NKLR	209 (4.24%)		42 (20.1%)	44 (21.0%)	1 (0.48%)	78 (37.3%)	2 (0.96%)	42 (20.1%)
MOON	8 (1.12%)	Medial Tibial Plateau	4 (50.0%)	2 (25.0%)	---	2 (25.0%)	---	---
NKLR	47 (0.95%)		6 (12.8%)	6 (12.8%)	---	21 (44.7%)	1 (2.13%)	17 (36.2%)
MOON	31 (4.35%)	Lateral Femoral Condyle	21 (67.7%)	1 (3.22%)	---	9 (29.0%)	---	---
NKLR	66 (1.34%)		13 (19.7%)	9 (13.64%)	---	33 (50.0%)	---	11 (16.7%)
MOON	54 (7.57%)	Lateral Tibial Plateau	30 (57.4%)	8 (14.8%)	---	15 (27.8%)	1 (1.85%)	---
NKLR	32 (0.65%)		1 (3.13%)	1 (3.13%)	2 (6.25%)	17 (53.1%)	---	11 (34.4%)

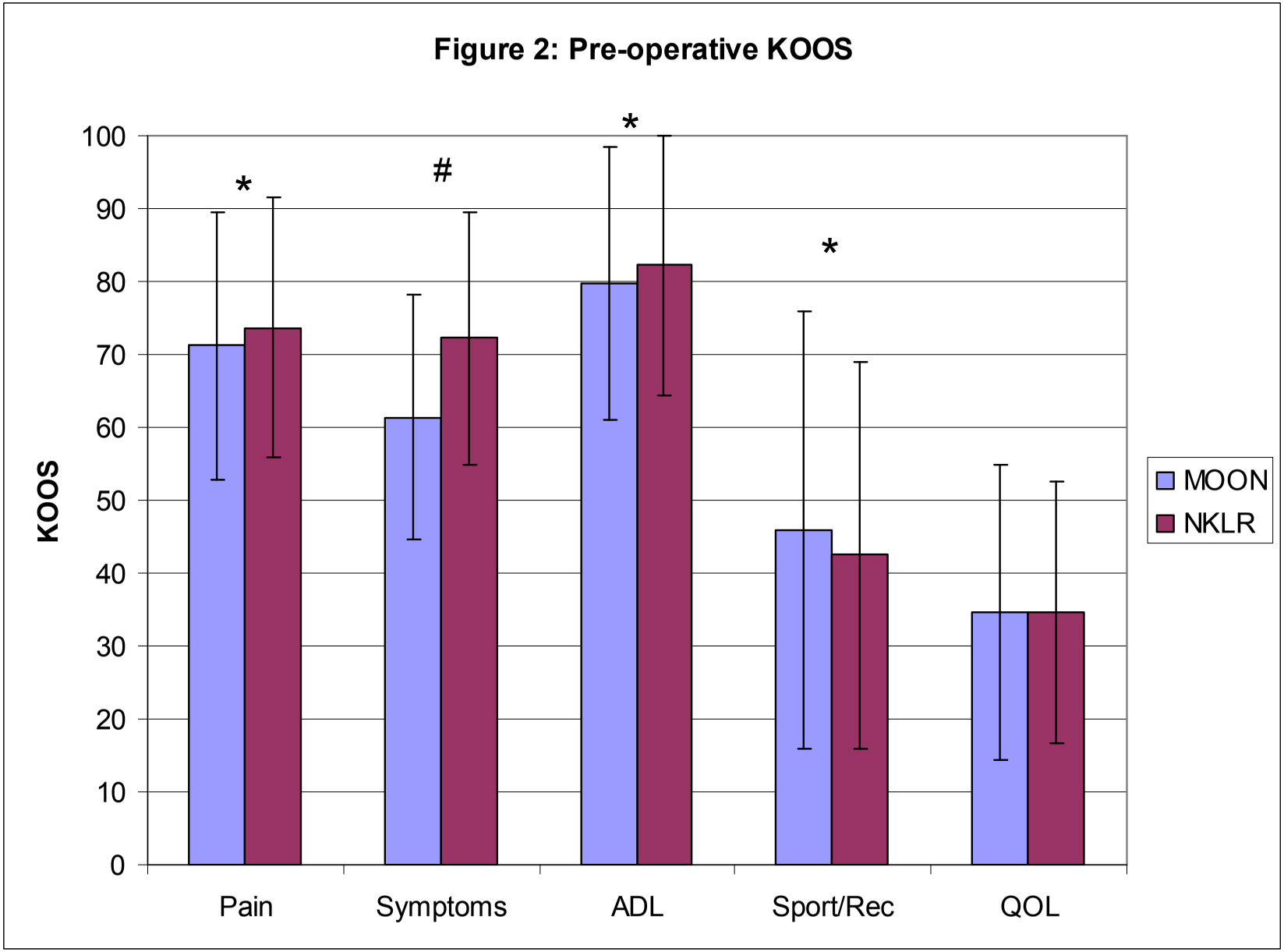
* MOON = Multicenter Orthopaedic Outcomes Network
# NKLR = Norwegian Knee Ligament Registry

Figure 1: Activty Associated with ACL Injury



* These sports had specific categories in only one database. In the other database they are represented under “other sport”

Figure 2: Pre-operative KOOS



* $p < 0.002$
# $p < 0.001$

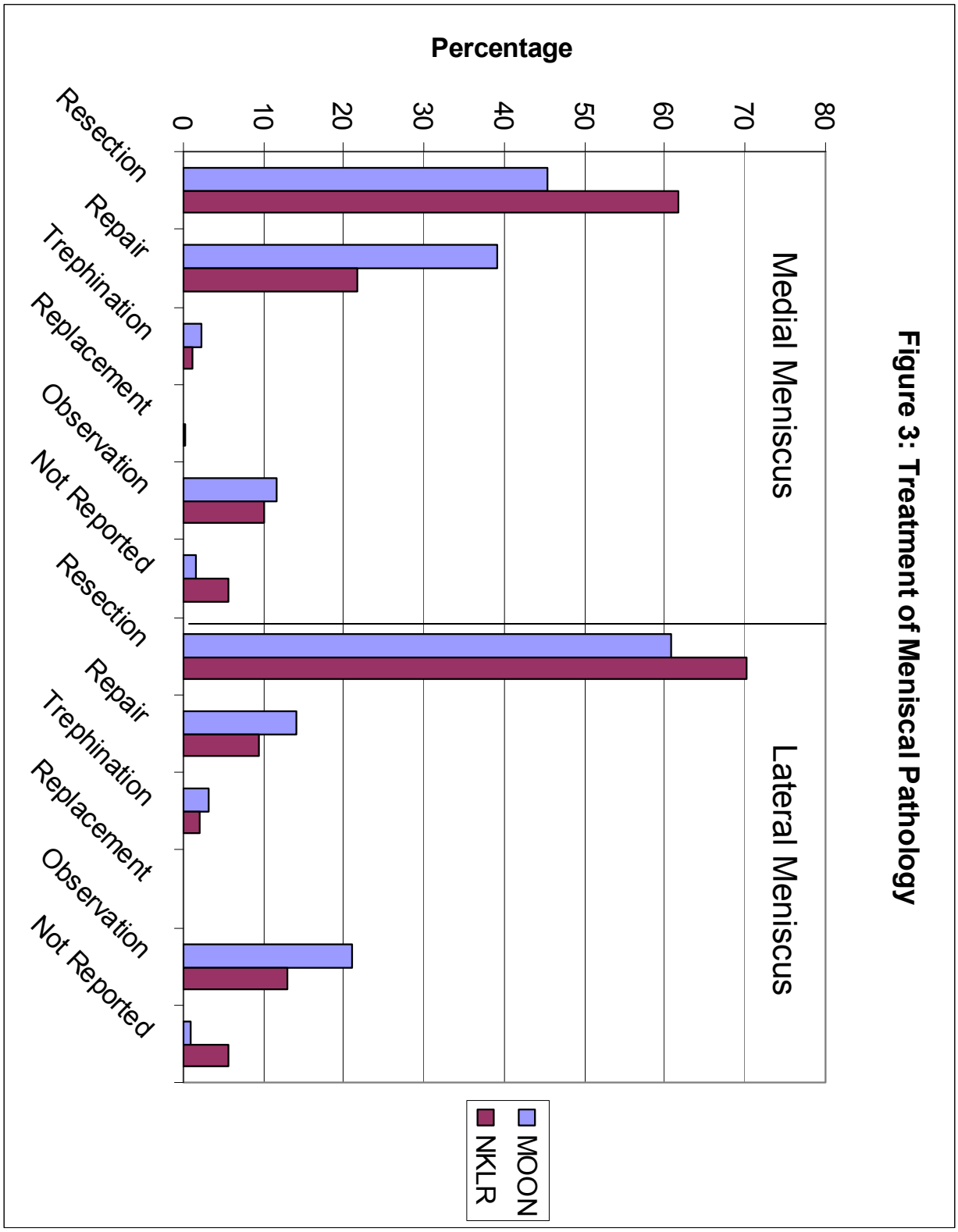
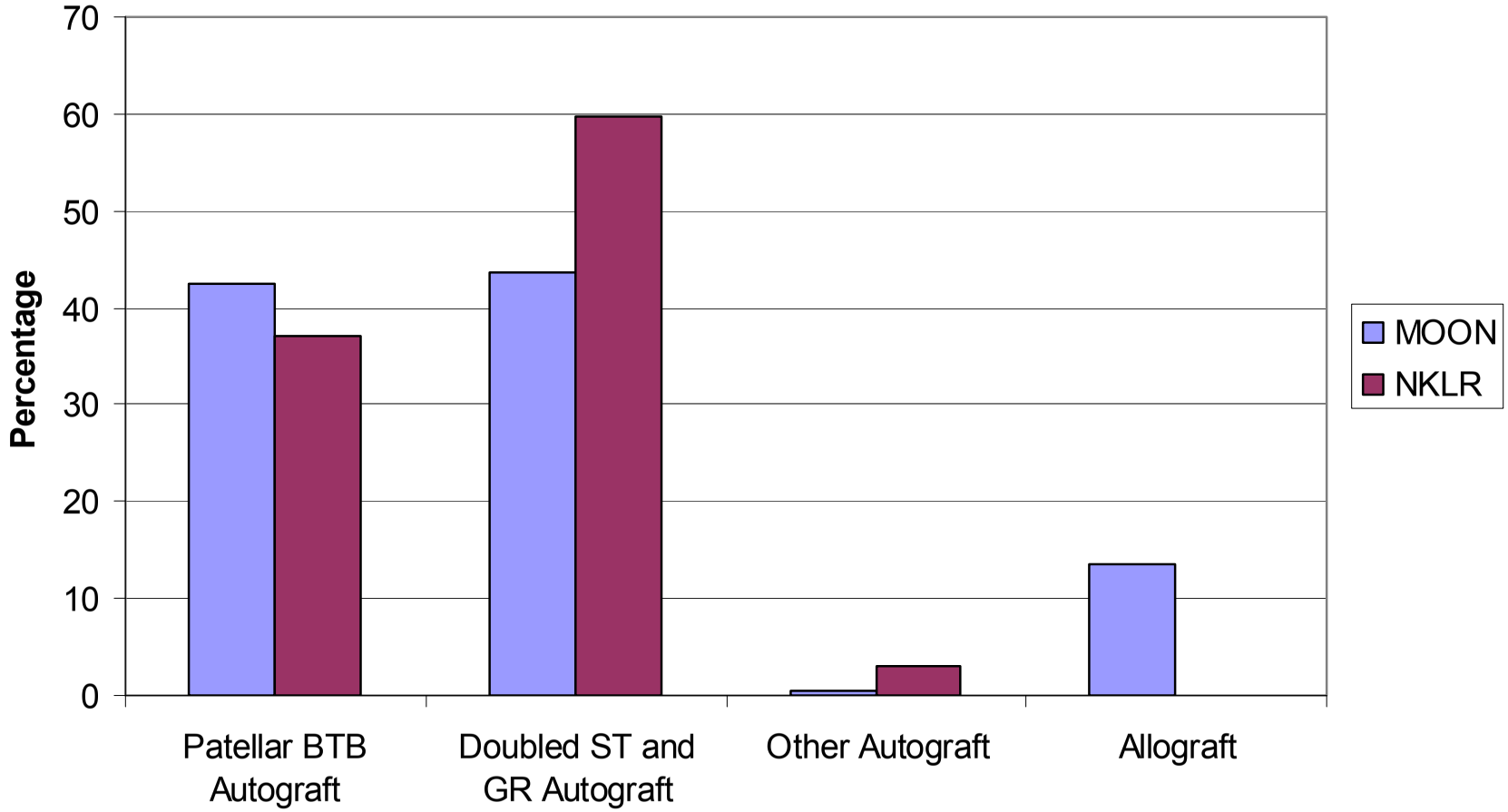


Figure 3: Treatment of Meniscal Pathology

Figure 4: ACL Graft Selection



BTB = Bone-Tendon-Bone
ST = Semitendinosus
GR = Gracilis

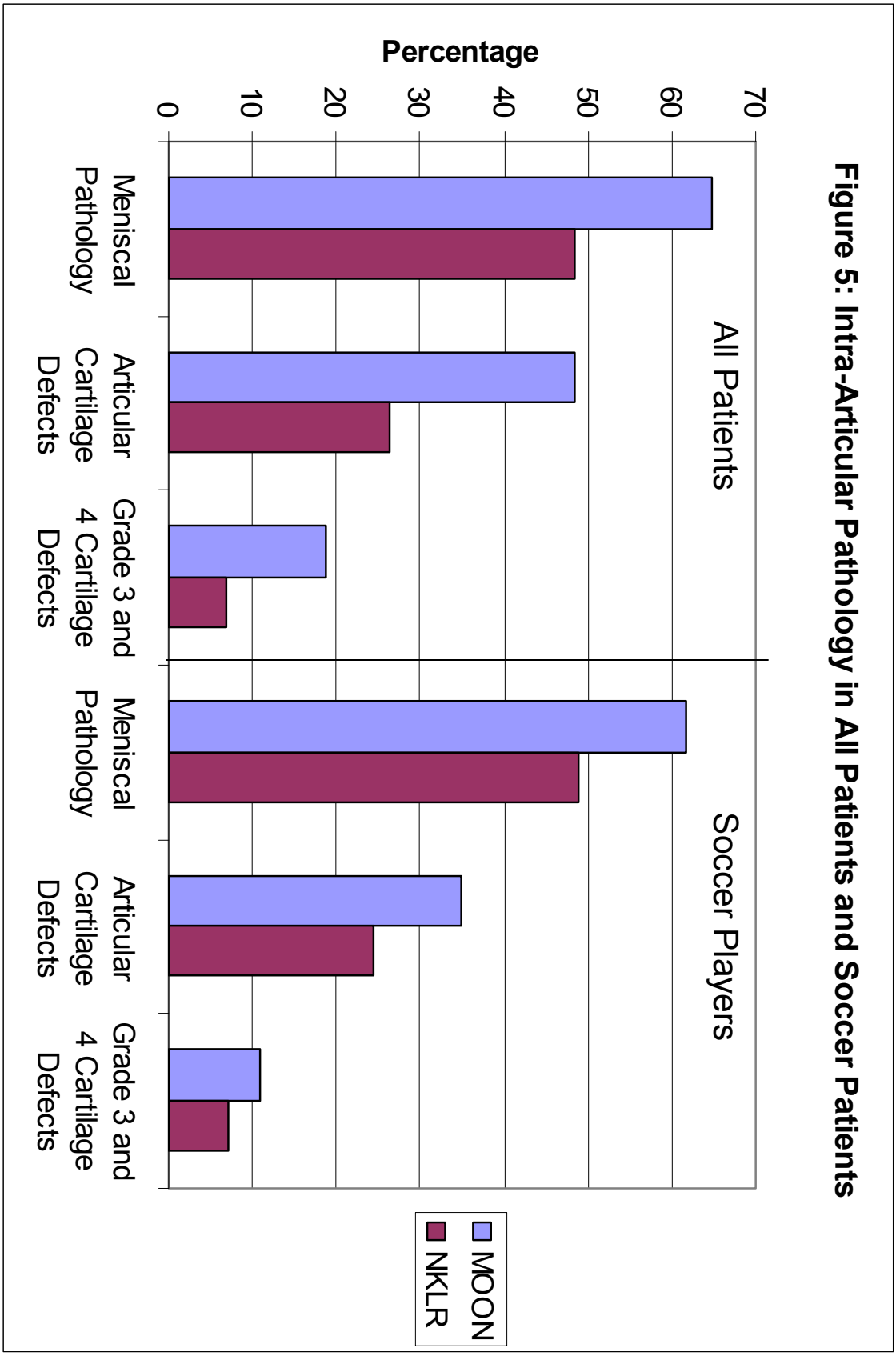


Figure 5: Intra-Articular Pathology in All Patients and Soccer Patients

Figure Legends

Figure 1: The activity associated with ACL injury is shown. Greater than 85 % of patients with a known mechanism of injury were injured playing a sport.

Figure 2: Pre-operative KOOS scores and statistically significant differences are shown. A clinically significant difference (greater than 8 points) is noted only in the "other symptoms" subscale.

Figure 3: Treatment of medial and lateral meniscal pathology in both the MOON and NKLR databases is shown. Resection is more commonly utilized in the NKLR database while repair (medial meniscus) and observation (lateral meniscus) are more common in the MOON database.

Figure 4: Graft selection for ACL reconstruction is shown. Hamstring autograft is more commonly utilized in the NKLR database while patellar tendon autograft is more common in the MOON database. Allograft is utilized much more frequently in the MOON database.

Figure 5: The incidence of meniscal and articular cartilage pathology in the MOON and NKLR databases are shown in all patients in the in the soccer subgroup. Higher rates are noted in the MOON database in both groups but the differences are smaller in the soccer subgroup.