

# The Clinical and Scientific Impact of an Institutional ACL Registry: Luxembourgish Experience

*Die Auswirkungen eines institutionellen Kreuzbandregisters am Beispiel der Sportklinik des Centre Hospitalier Luxembourg*

## Summary

- › **A standardized clinical pathway/registry** for ACL injuries was developed in 2011 in our institution to monitor patient, injury and clinical profiles on a systematic basis regardless of operative or non-operative treatment. It was aimed from the very beginning for both patient care and research purposes.
- › **The aim of this paper** is to share the Luxembourgish experience of this in-house registry, from its organization to the results of its publications.
- › **Our findings indicated** that there was not only a big inter-individual variability of physiological knee structures, but also of injury types, thereby showing that isolated ACL injuries were rare and that a personalized medicine approach of ACL injuries is required.
- › **Our findings about individual patient profiles**, structural soft-tissue damage such as meniscal injuries, as well as factors contributing to the potential decompensation of knee laxity over time are some of the major discoveries over the last decade. Other findings such as the periodicity of ACL injuries in organized team ball sports, the high variability of knee morphology, references to understand the course/progression of ACL reconstructed patients and movement analyses are also of great value to reach high quality in patient care and continuous innovation in knee surgery.

## KEY WORDS:

Anterior Cruciate Ligament Injuries, Clinical Pathway, Epidemiology, Knee Laxity, Outcomes, Meniscus

## Zusammenfassung

- › **In unserer Einrichtung** wurde 2011 ein standardisierter klinischer Behandlungspfad/ein Register für VKB (Vordere Knieband)-Verletzungen entwickelt, um Patienten-, Verletzungs- und medizinische Profile bei operativer ebenso wie konservativer Behandlung systematisch zu erfassen. Es diente von vornherein sowohl der Patientenversorgung als auch zu Forschungszwecken.
- › **Ziel dieses Artikels** ist es die luxemburgischen Erfahrungen mit diesem hausinternen Register zu teilen, von der Organisation bis hin zu seinen Publikationsergebnissen.
- › **Unsere Untersuchungen weisen darauf hin**, dass es nicht nur große interindividuelle Unterschiede der physiologischen Kniestrukturen, sondern auch verschiedene Verletzungsarten gibt. Dadurch konnte gezeigt werden, dass isolierte VKB-Verletzungen selten sind und einen personalisierten medizinischen Ansatz erfordern.
- › **Unsere Erkenntnisse zu individuellen Patientenprofilen**, strukturellen Weichteilschäden wie Meniskusverletzungen sowie Faktoren, die im Laufe der Zeit zur möglichen Dekompensation der Kniegelenkslaxität beitragen, gehören zu den wichtigsten Erkenntnissen des letzten Jahrzehnts. Andere Ergebnisse umfassen die Häufigkeit von VKB-Verletzungen in organisierten Mannschaftssportarten und die hohe Varianz der Kniemorphologie sowie Beiträge zum Verständnis des Verlaufs/des Fortschritts von Patienten mit VKB-Rekonstruktion und Bewegungsanalysen. Diese Ergebnisse sind ebenfalls von großer Bedeutung, um einen hohen Standard in der Patientenversorgung zu erreichen und den kontinuierlichen Fortschritt der Kniechirurgie zu gewährleisten.

## SCHLÜSSELWÖRTER:

Vordere Kreuzbandverletzungen, Klinischer Behandlungspfad, Epidemiologie, Knie laxität, Ergebnisse, Meniskus

## Introduction

In the 2000's, anterior cruciate ligament (ACL) registries were initiated to evaluate trends in treatment and increase the standards of care of this severe knee injury (7, 8). The first national ACL registries were created in Scandinavia in 2004 (10, 16), followed by UK (35) and New Zealand (37) in 2014 and Germany in 2017 (33). Other initiatives include registries from integrated health care system such as the Kaiser Permanente ACL registry gathering data from more than 50 hospitals (23), hospital based registries such as the Hospital for Special Surgery

ACL Registry (24) or the Luxembourgish registry (44) or large multicenter cohort studies such as the Multicenter Orthopedic Outcomes Network (MOON NCT00478894) or the Multicenter ACL Revision Study (MARS NCT00625885). In 2021, and despite these early initiatives, a systematic recording of data of patients with ACL injuries still remains at its beginnings. Most registries do not include patients being treated non-operatively, although this is known to be a valuable option for some patients (11). Furthermore, unlike clinical studies, registries >

## REVIEW

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Table 1

Overview of the outcomes gathered for adults with an ACL reconstruction during a knee evaluation at the physiotherapy department. The appointments and testing procedures are adapted according to age (pediatric or adult), treatment (conservative or surgical) and surgical procedures (for meniscal repair delayed to 8 weeks and 4 months, for associated ligament reconstruction delayed to 3 or 6 months, etc).

PROTOCOL / ADDITIONAL INFORMATION		PRE OP	6-8 WEEKS	3-4 MONTHS	6 MONTHS	12 MONTHS	24 MONTHS
<b>Questionnaire about patient, injury and sport practice</b>	Home- made questionnaire	X	X	X	X	X	X
<b>Isokinetics (Contrex®)</b>	Average peak torques of 4 repetitions of concentric hamstring and quadriceps force (60°/s) and eccentric hamstring force (30°/s)	X		X	X	X	X
<b>Hop tests Hop for distance, vertical jump and side hop according to Gustavsson et al. (12))</b>	Admission criteria: deficit of knee flexors / extensors under 40%, IKDC score over 70, no swelling, no knee pain, free ROM, negative pivot shift, subjective knee stability				X	X	X
<b>Knee laxity (GNRB® (GeNouRoB) / Rotameter according to Mouton et al. (30))</b>	Average of the 2 last trials out of 3 up to 200 N Average of the 2 last trials out of 4 in internal rotation up to 6 Nm	X		X	X	X	X
<b>Patient reported outcome</b>	Knee Injury and Osteoarthritis Outcome Score (KOOS) (38): scores from 0 to 100 (= no knee problems) for the 5 subscales (pain, symptoms, activity of daily living, sports, quality of life). International Knee Documentation Committee (IKDC) subjective forms (13): score from 0 to 100 (= no limitation with daily or sporting activities and absence of symptoms)	X	X	X	X	X	X

usually collect incomplete information about the therapeutic procedure and its outcomes. In our institution, a standardized clinical pathway for patients with ACL injuries was developed to systematically monitor patient, injury and clinical profiles. The aim of this narrative review is to share the Luxemburgish experience of this in-house registry from its organization to key learning issues.

**The Organization of the ACL Clinical Pathway/Registry**

The ACL clinical pathway is a hospital-based registry started in March 2011 at the Sports Clinic of the “Centre Hospitalier de Luxembourg” (CHL). It is focusing on patients with ACL injuries treated in this institution, regardless whether an operative or a non-operative treatment was chosen. From the start, the registry was designed to gain both better insights of patient care and to do clinical research to improve the understanding of ACL-injured knees and eventually improve and personalize treatments. To allow using the data for research purposes, patients are asked to give their written consent to use the medical data gathered during the treatment period of their ACL injury. The protocol was approved by the National Ethics Committee for Research (N°201101/05).

The ACL clinical pathway considers the different components of health condition (body functions, structures, activities and participation) as presented in the International Classification of Functioning, Disability and Health (ICF) of the World Health Organization (WHO). All data were prospectively collected. Imaging data (MRI, X-rays) were acquired on a regu-

lar basis and surgical data using paper forms filled in by the surgeons. Patient outcomes were gathered during specific knee evaluation at the physiotherapy department. The follow-up is both standardized and personalized according to patient, injury and clinical profiles. It is adapted to age (pediatric or adult), treatment (conservative or surgical) and surgical procedures, including not only data on the type of ACL reconstruction procedure, but also on associated meniscal, ligament or cartilage surgeries. An overview of the outcomes gathered for surgically treated adult patients is available in Table 1. In case of data completeness, more than a thousand individual data per follow-up are recorded in the database.

All data are saved by an interdisciplinary team of healthcare professionals and scientists using a dedicated software. It offers different functionalities to handle patient consent agreement for research, missing data and reminders for appointments. It also creates automatic reports for knee evaluations and data can be exported in a standardized format for statistical analyses. The software is checked on a daily basis with the help of a research nurse and a scientific coordinator to ensure patient follow-up and data quality, with respect to consistency, accuracy and completeness.

**Included Patients and Treatments: Evolution over the Years**

In 10 years, 2224 ACL injuries of 2073 patients (62% males) could be seen in the CHL Sports Clinic. Overall, the number of included patients with ACL injuries has increased over years, reaching up to an annual inclusion of up to 300 patients

(Figure 1). The gradual standardization of registration procedures and the increased adoption of the clinical pathway by all in-hospital stakeholders resulted in this increased numbers of operatively and non-operatively treated patients over years.

In 64% (n=1429) of the ACL injuries, patients underwent an ACL reconstruction. The median age at surgery was 26 years (percentile 25: 20 – percentile 75: 34) and the median age at first consultation of patients which were treated non-operatively was 37 years (28-45). Of the 1409 recorded ACL reconstructions, 184 (13%) were ACL revision surgeries. The ACL reconstruction was associated with other procedures in 814 (n=58%) cases (cartilage, meniscus, associated ligament procedures or osteotomies). The standardized clinical pathway allowed the identification of surgical trends over the years. As an example, we chose to illustrate the

first 250 with the last 250 recorded ACL-reconstructions. Key findings are summarized in Table 2 and 3. The main observed trends are related to graft choice (decrease of patellar tendon versus massive increase of quadriceps tendon grafts) and associated procedures like lateral extraarticular tenodesis (from 0 to 14%) and meniscus repair (from 31% to 47%), of which especially lateral meniscus repair procedures (from 16% to 39,5%).

#### Peer-Reviewed Publications Originating from the ACL Clinical Pathway/Registry

The rate of signed written consent forms has increased from 71 % in 2011 to 84% at the beginning of 2021, showing the constantly provided effort to improve the registry. This enabled the registry stakeholders to analyze the data and eventually publish the results. A total of 20 peer reviewed articles were thus published in this 10 years-period (18 Medline and 2 non-Medline referenced journals; Table 4). They can roughly be divided into 4 categories of studies related to: (1) the epidemiology of ACL injuries, (2) the understanding of normal and pathological knee laxity, (3) ACL injury profiles with a specific attention to associated meniscus injuries, and (4) ACL reconstruction outcomes through functional and biomechanical assessments. The following paragraphs will summarize the main findings of these studies according to their direct impact on (1) primary prevention, (2) injury diagnosis and treatment and (3) patient outcomes and secondary prevention.

#### Peer-Reviewed Publications with Impact on Primary Prevention

##### Epidemiology: Periodicity of ACL Injuries

During daily clinical practice, it appeared that there was a strong seasonal variation in the occurrence of those ACL injuries which were not related to winter sports. Therefore, a study was initiated to analyze the distribution of ACL injuries during the athletic season in nonprofessional soccer, handball, and basketball (Figure 2). Almost one third of the injuries (28%) occurred immediately

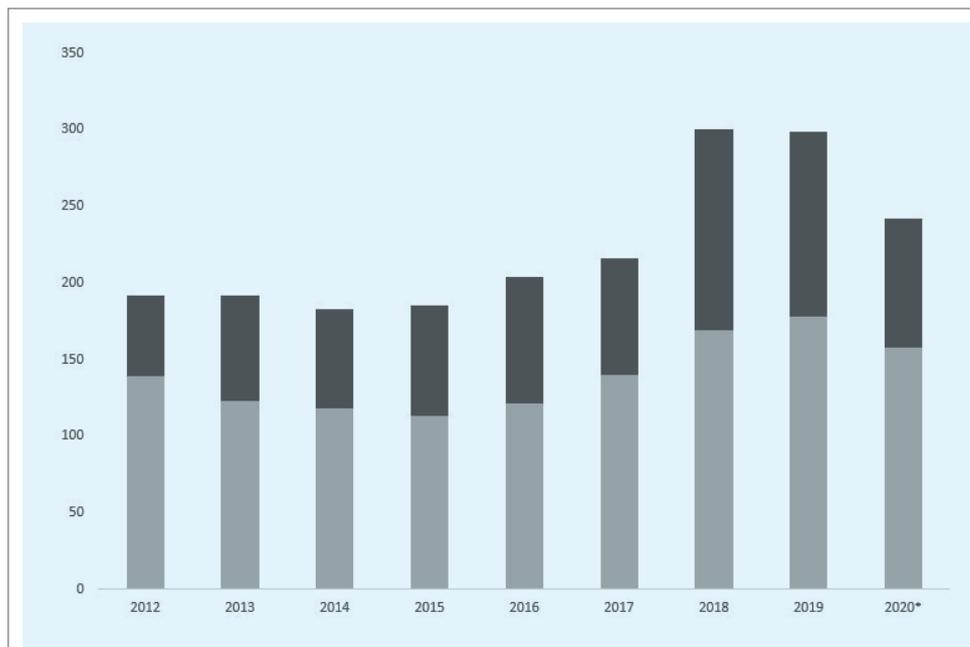


Figure 1

Number of ACL injuries seen at the Sports Clinic over the years. Grey: operated patients. Dark grey: non-operated Patients. Year 2011 and 2021 are not displayed as data do not represent a full calendar year. \*The decrease from 2019 to 2020 can be explained by the pandemic effect.

after the summer break in the first two months of the season (27). This has been rarely reported before and was in line with some recent publications on National Collegiate athletes in basketball, Lacrosse and football (1), as well as on professional male football players (6). A combination of sudden training peaks and/or match load and a lack of physical fitness and cumulative fatigue could explain this periodic high amount of injuries. These findings are important for coaches, physical fitness trainers and team physicians to allow their athletes to have a safe start of the season, e.g. by implementing specific ACL injury prevention initiatives.

##### Knee Laxity: Healthy Knees

A significant amount of research efforts went into the measurement of knee laxity with innovative devices measuring antero-posterior and rotational laxity. It could be identified that anterior and rotational knee laxities are highly variable between subjects, poorly related to each other (30) and subjected to the influence of individual characteristics like gender or body mass (29). Female knees have for instance a rotational laxity which is in average 30% superior to male knees. Likewise, the healthy contralateral knees of a cohort of patients with noncontact ACL injuries, internal rotation and anterior displacement have shown to be increased compared to the knees of a non-injured control population (32). This suggests that some patients do have specific knee laxity profiles putting them at a higher risk to undergo a noncontact ACL injury. Identifying these individual risk profiles may therefore be of relevance for the prevention or treatment of ACL injuries.

#### Peer-Reviewed Publications with Impact on Injury Diagnosis and Treatment

##### Epidemiology of ACL Injuries: Patient Profiles and Treatment Practice

One of the first publications resulting from the registry dealt with the understanding of patient profiles and its influence on the therapeutic decision making. Three-hundred forty-six surgically and non-surgically treated patients (222 males >

Table 2

Surgical trends over the years: comparison of the first 250 recorded ACL reconstructions with the last 250 ACL-reconstructions (out of 1409 ACL reconstructions performed within the Sports Clinic).

	FIRST 250 RECORDED ACL RECONSTRUCTIONS	LAST 250 RECORDED ACL RECONSTRUCTIONS
<b>Period of recording</b>	March 2011 – March 2013 48 months	November 2019 – July 2021 44 months
<b>Gender</b>	176 males / 74 females (70% / 30%)	161 males / 89 females (64% / 36%)
<b>Age at surgery (median and percentiles 25-75)</b>	25 (19-34)	28 (22-36)
<b>Revision</b>	26 (10%)	37 (15%)
<b>Grafts used for ACL reconstruction</b>	Patellar tendon: 142 (57%)	Patellar tendon: 89 (35.5%)
	Semitendinosus / Gracilis: 98 (39%)	Semitendinosus / Gracilis: 75 (30%)
	Quadriceps: 7 (3%)	Quadriceps: 85 (34%)
	Other: 3 (1%)	Other: 1 (0.5%)
<b>Associated procedures (i.e. cartilage, meniscus, associated ligament procedures or osteotomies)</b>	120 (48%) of which 4 (3%) with 2 associated procedures	169 (68%) of which 37 (22%) with 2 associated procedures
<b>Lateral extra-articular tenodesis</b>	0 (0%)	34 (14%)
<b>Meniscal procedures (for details see Table 3)</b>	109 (44%)	145 (58%)

Table 3

Surgical trends over the years: detailed description of the associated meniscus procedures - comparison of the first with the last 250 ACL-reconstructions (out of 1409 procedures performed at the Sports Clinic).

	MENISCAL PROCEDURES	PARTIAL MENISCECTOMY		MENISCAL REPAIR	
<b>First 250 recorded ACL reconstructions</b>	109 (44%)	40 (16%)	Medial: 22 (9%)	77 (31%)	Medial: 46 (18%)
			Lateral: 20 (8%)		Lateral: 38 (15%)
			Of which 2 (1%) bimeniscal		Of which 7 (3%) bimeniscal
<b>Last 250 recorded ACL reconstructions</b>	145 (58%)	39 (15.5%)	Medial: 28 (11%)	118 (47%)	Medial: 54 (21,5%)
			Lateral: 15 (6%)		Lateral: 98 (39%)
			Of which 4 (1.5%) bimeniscal		Of which 34 (14%) bimeniscal

and 124 females; age at injury: 30 ± 11 years) were studied (40). In agreement with other registries (57 to 72% male population) (36), males were predominant. Half of male patients were between 21 and 35 years old at the time of injury. Before the age of 35, they were most likely to be injured in level-I sports (11) (handball, soccer, basketball). In females, 2 peaks of patients were predominant: one in the under 20 years age group and one after the age of 35. In the latter, most injuries occurred in level-II sports (11) like alpine skiing. To date, a similar peak of injuries in female patients over the age of 35 could only be identified in the Danish Ligament Reconstruction Registry (16).

In the overall cohort, 74% of patients underwent an ACL reconstruction (40). This percentage was highly depending on the patient profile. Overall, 8 profiles could be identified according to gender, age, preinjury level of sports practice and previous ACL injuries. Patients below 35 years of age which were involved in a competitive sport before the injury were most likely to undergo surgical treatment (>80%). The rate of surgical treatments decreased to 60–80% in patients which were younger than 35 years of age, and who were not involved in competitive sports before the injury. Finally, the percentage of operated patients was inferior to 60% in patients above the age of 35.

The documented overall ratios were similar to the “rule of thirds” concept popularized by Noyes et al. (34), as well as to later prospective studies addressing the therapeutic deci-

sion-making process (9, 11), stating that about one third of patients were able to compensate their injury without surgery. These observations reflected that therapeutic decision making was heavily dependent on patients’ age and activity profile. Although the line of distinction between surgical and non-surgical treatment could not be clearly drawn through these findings, understanding the diversity of patient profiles consulting in a sports clinic was an important step to gain a global overview of treated patients and eventually develop a more personalized approach to these severe sports injuries.

**Knee Laxity: Diagnosis**

If an ACL injury is suspected in an injured knee, current diagnostic measures like clinical examination and MRI generally allow for a correct diagnosis. However, none of these traditional methods allows for a 100% reliable decision-making. Having additional tools like laxity measurement devices available for such cases is therefore important. Our research has shown that these devices are highly reliable and that adding rotational to the more traditional sagittal laxity measurements improves the sensitivity by 12 %, leading to an overall excellent diagnostic value for ACL injury of 98% (Positive Predictive Value) (31). The experience that was gained through these scientific evaluations led to the systematic use of knee laxity measurements in the daily clinical practice for the diagnosis and follow-up

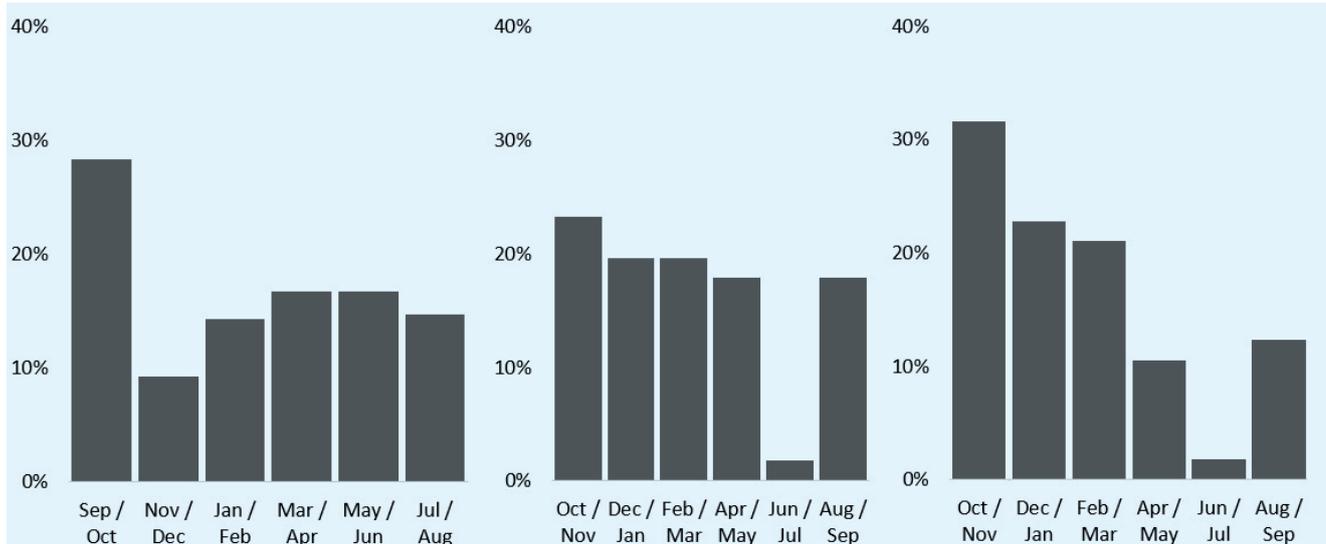


Figure 2

Distribution of ACL injuries during the season in nonprofessional soccer (left), handball (middle), and basketball (right). Adapted from (27).

of patients. They add valuable information about the ligament / graft status in a minimum amount of time as they can be performed on site in less than 10 minutes.

Current efforts on the evaluation of diagnostic criteria try to improve the understanding of the natural history of ACL injuries and reconstructions with respect to sagittal tibiofemoral displacement. Data from the registry could here show that a high lateral meniscal slope ( $\geq 4.0^\circ$ ) on preoperative MRI led to an increased risk of having an abnormal side-to-side difference in ATT one year after primary ACL reconstruction (Positive Predictive Value 94%) (42).

### Injury Profiles: Identifying the Full Range of Meniscal Damage

Several publications generated from the registry dealt with morphological intraoperative findings. Until a few years ago, associated intra- or extraarticular lesions of the ACL-injured knee like injuries of the anterolateral structures or specific meniscus injuries were either neglected or insufficiently recognized. With the improvement of surgical techniques and the evolution of imaging procedures, the understanding of the importance of these structures for later knee function however gradually increased over the last decade. In this respect, we did especially focus on the impact of specific meniscus injuries like ramp lesions, root tears and subtle meniscus instabilities.

Registry data showed more than two-thirds of patients with ACL reconstruction displayed additional meniscal injuries. This is much more than reports from some other registries (36), but can be explained by a meticulous arthroscopic inspection and inclusion of ramp lesions or various types of root tears which are sometimes difficult to identify. Medial meniscus ramp lesions and posterolateral root tears, represented half of these lesions (22). Due to their impact on knee laxity (26, 28), their systematic identification and repair should become the gold standard in order to limit residual laxity after ACL reconstruction or graft failure. Their diagnosis is rarely possible with preoperative imaging and quite limited with routine arthroscopic inspection of the knee joint so that a deeper understanding of factors associated to these lesions may help to improve their identification. As an example, registry data revealed that medial meniscus ramp lesions are present in 1 out of 4 patients undergoing an ACL reconstruction (22) and are likely to be associated with

complete ACL tears (39), posteromedial bone bruise on MRI (4), contact injuries (39) and preoperative grade III pivot shift test (28). Other associated factors such as being a male, age under 30, revision ACL reconstruction, chronicity and concomitant lateral meniscal tears have also been reported (41).

The instability of the posterior horn of the lateral meniscus (PHLM) is another under recognized entity where neither modern imaging techniques nor arthroscopic inspection are sufficiently reliable diagnostic procedures. Therefore, a new arthroscopic screening test called "the aspiration test" was described by our team (15). This test showed to be superior to arthroscopic probing and revealed an instability of the posterior horn of the lateral meniscus in almost one third of patients with an ACL injury (14). This finding led to an increasing number of lateral meniscal repair procedures during ACL reconstruction in our center. The described research efforts thus added evidence to the current efforts to get a better understanding of the entire spectrum of structural damage occurring in an ACL injured knee.

### Injury Profiles: Structural Soft-Tissue Damage and Knee Laxity Decomensation

Further evidence is needed to say if extensive repair of these so-called "new" meniscus lesions will improve the clinical outcome of patients with ACL reconstruction. Prior to this, it is therefore important to evaluate if their presence impacts the natural history of ACL injured knees.

As mentioned before, an association between the presence of medial meniscus ramp lesions and high-grade rotational laxity (grade III pivot shift) could be identified (28). In a later study, patients with complete chronic ACL injuries (> 6 months from injury to surgery) and bimeniscal tears were found to be more likely to have a preoperative grade III pivot shift than their acute counterparts (21). This relation between time from injury and the magnitude of the pivot shift may thus be an early sign of rotational knee laxity decomensation.

A similar relation between time from injury, meniscal status and knee laxity could be found in another recent study where lateral monopodal weightbearing radiographs were performed. This simple standard radiographic technique was developed in the 1990's in Lyon (5) and proved to be valuable in evaluating sagittal tibiofemoral displacement under knee loading conditions. The study revealed that the difference in ATT between both >

Table 4

Summary of peer reviewed publications generated from the registry data and main findings.

THEMATIC	MAIN FINDINGS
<b>Epidemiology of ACL injuries: Patient profiles and treatment practice (36, 40)</b>	<ul style="list-style-type: none"> <li>+ Male patients: 50% of ACL injuries between 21-35 years old, likely to be injured in level-I sports (handball, soccer, basketball) under 35. Above 35, more females injured than males, mainly in alpine skiing</li> <li>+ Therapeutic decision making heavily dependent on patient profile</li> <li>- &gt;80% surgical treatment: under 35, involved in a competitive sport before the injury</li> <li>- 60-80% surgical treatment: under 35, not involved in competitive sports before the injury</li> <li>- &lt;60% surgical treatment in patients above the age of 35</li> </ul>
<b>Epidemiology: Periodicity of ACL injuries (27)</b>	<ul style="list-style-type: none"> <li>+ 28% of ACL injuries immediately after the summer break (first two months of the season) in nonprofessional soccer, handball, basketball</li> </ul>
<b>Knee laxity: Healthy knees and diagnosis (29-32, 42)</b>	<ul style="list-style-type: none"> <li>+ Anterior / rotational knee laxities: highly variable between subjects, poorly related to each other, subjected to the influence of individual characteristics like gender or body mass</li> <li>+ Healthy contralateral knees of patients with noncontact ACL injuries: internal rotation and anterior displacement increased compared to non-injured control population</li> <li>+ Combining anterior/ rotational knee laxities → Positive Predictive Value for ACL injury: 98%</li> <li>+ Increased lateral meniscal slope on preoperative MRI (<math>\geq 4.0^\circ</math>) → Increased risk of abnormal side-to-side difference in anterior laxity one year after primary ACL reconstruction (Positive Predictive Value 94%)</li> </ul>
<b>Injury profiles: Identifying the full range of meniscal damage, structural soft-tissue damage and knee decompensation (4, 14, 15, 17, 21, 22, 28, 39)</b>	<ul style="list-style-type: none"> <li>+ Meniscal injuries: Almost 2/3 of ACL-reconstructed patients</li> <li>+ Medial meniscus ramp lesions + posterolateral root tears = half of meniscal lesions</li> <li>+ Medial meniscus ramp lesions: 1/4 patients undergoing ACL reconstruction, likely to be associated with complete ACL tears, posteromedial bone bruise on MRI, contact injuries, preoperative grade III pivot shift</li> <li>+ Instability of the posterior horn of the lateral meniscus → new arthroscopic screening test: aspiration test, superior to arthroscopic probing, revealed this instability in almost 1/3 of ACL reconstructed patients</li> <li>+ Patients with complete chronic ACL injuries (&gt; 6 months from injury) + bimeniscal tears: more likely to have a preoperative grade III pivot shift than their acute counterparts → early sign of rotational knee laxity decompensation</li> <li>+ Secondary ACL deficiencies, patients with time from injury greater than 4 years and with at least one meniscal tear: increased difference of anterior tibial translation on lateral monopodal weightbearing radiographs</li> </ul>
<b>ACL reconstruction outcomes: Functional and biomechanical assessment (18, 25, 43, 44)</b>	<ul style="list-style-type: none"> <li>+ Younger patients (&lt; 30) → higher IKDC median score (6–9 points) before/within the first year after ACL reconstruction</li> <li>+ Hamstrings graft → higher KOOS median scores (2–15 points) than patellar tendon graft until 6 months after ACL reconstruction</li> <li>+ 9 months after ACL reconstruction: patients still employ a knee unloading strategy during bilateral landing although they can perform strenuous lateral hop tests on both legs similarly to healthy controls without altered parameters</li> </ul>

knees was significantly greater in secondary ACL deficiencies, in patients with no previous ACL reconstruction and a time from injury greater than 4 years and with at least one meniscal tear (17).

These two studies by Magosch et al. and Macchiarola et al. suggested that both sagittal laxity as expressed by ATT and rotational laxity as expressed by the degree of pivot shift increase over time when compensatory soft tissue mechanisms of the knee are exceeded. An early diagnosis of the total amount of soft tissue damage going beyond the injured ACL seems therefore to be crucial to identify patients who may be at higher risk to undergo later knee laxity decompensation. In these patients, early ACL reconstruction and extensive meniscal repair may help to prevent later ACL reconstruction failure (19, 20) and poor functional outcomes (2). To complete the picture of associated lesions, other ligament ruptures, lesions to the anterolateral complex and chondral lesions should however also be considered in the personalization of an individual patient's treatment.

Peer-Reviewed Publications with Impact on Patient Outcomes and Secondary Prevention

**ACL Reconstruction Outcomes: Functional Assessment**

Following patients' outcomes after ACL reconstruction is of importance to provide patients with a better post-operative guidance. To this end, the natural course/progression of patients after ACL reconstruction has to be studied and in-house

references established in order to detect patients with lower outcomes (44). These are useful both for quality control and for internal and external benchmarking. In the registry, patient related outcomes are assessed with the KOOS (38) and IKDC 2000 (13). It could be shown that they were mostly influenced by graft type and age, respectively (18). Younger patients (< 30 years of age) had consistently a higher IKDC 2000 median score (6–9 points) before and within the first year after surgery. The median scores of the KOOS subscales were 2–15 points higher in patients with hamstrings grafts compared to patients with patellar tendon grafts until 6 months after the ACL reconstruction. This difference was no longer present at 12 months after the surgery.

**ACL Reconstruction Outcomes: Biomechanical Assessment**

Detecting and correcting asymmetric landing strategies can be relevant in the framework of personalized rehabilitation and may help to prevent secondary injuries. In the clinical pathway, movement analyses are therefore systematically performed in patients who are at higher risk for recurrent injuries, especially in young patients involved in competitive pivoting sports. These measurements are of particular interest to detect remaining functional impairments. It could indeed be confirmed that despite the routinely recommended structured rehabilitation program, many patients continued to employ a knee unloading strategy of their involved leg during bilateral landing at

9 months after ACL reconstruction (25). Interestingly, similar patients were able to perform strenuous lateral hops tests and achieved similar results than healthy active controls, without altered spatiotemporal or loading parameters (43). This confirmed previous studies showing that unloading compensations may only occur during a two-legged task (3) and showed the limitations of hop tests. These findings may be of value to understand the reasons of the high amount of secondary ACL injuries, especially in patients under the age of 20. Further studies are needed to allow for a safer return to sports and eventually reduce the number of secondary injuries.

### Strengths, Limitations and Future Perspectives of the Clinical Pathway And Registry

The main strength of this clinical pathway/registry is that it is standardized, institutionalized and that in-depth data are provided to ensure that a reasonable picture of the patient, injury and clinical profiles is obtained. There is continuous flow of data with a strong multidisciplinary collaboration which helps to ensure internal validity and data consistency over time. The research coordinator ensures data accuracy and coherence on a weekly basis with the help of a specific software. A dedicated nurse ensures patient follow-up, which limits the proportion of patients lost to follow-up and ensures data completeness. This helps to rapidly implement new findings into clinical practice and vice-versa and thus allows to achieve a high-level quality control in patient care. In addition, this represents a strong basis for high quality scientific research. Research hypotheses are original and clinically driven, which means that they are highly relevant to the field of orthopedic patient care.

The greatest challenge remains the daily organization of the clinical pathway/registry. First, it requires dedicated staff as well as a dedicated software for which funding needs to be secured. Despite this high-level quality patient care and research data, there is still room for improvement. The current registry is not designed to assess intra- or perioperative complications, nor does it include data to monitor rehabilitation or patient care. Likewise, patient adherence and compliance remain a major limitation of this single-center registry. As acquisition of data is essentially made on-site, patients who change their treatment center or physician are lost to follow up which is the reason why implementing remote monitoring processes is currently being considered.

Continuous efforts are also being made to increase the recruitment rate. The rate of signed written consent forms has increased from 71 % in 2011 to 84% at the beginning of 2021. Some patients are not willing to take part in the registry although the percentage of definitive refusal is low (estimated to less than 5%). This means that the consent status of about 10 to 15% of patients seen on site needs to be improved.

Despite these limitations, such a registry offers many opportunities like those cited above. Above all, it guarantees high quality patient care and allows to continuously monitor medical practice. Likewise, the registry includes conservatively treated patients which is extremely difficult in daily clinical practice. Future work will allow to analyze these data to improve the understanding of the natural history of ACL injured

knees and to further individualize treatment approaches for patients with ACL injuries.

### Conclusion

The impact of a single-institution ACL injury pathway is manifold. It provides a precise epidemiological picture of ACL injured patients and their individual patient profiles, knee injury and treatment characteristics as well as related clinical profiles. The observed surgical trends over time showed an important change of the surgical behaviors. The main findings concerned the type of used autologous tendon grafts for ACL reconstruction as well as a significant increase of associated surgical procedures like lateral extraarticular tenodesis and meniscal repair. Through its strong multidisciplinary and multifactorial approach, the ACL clinical pathway allowed to establish a high level of quality control and standardization of patient care as well as to generate innovative findings through scientific research. ■

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### Conflict of Interest

*The authors have no conflict of interest.*

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## Die Auswirkungen eines institutionellen Kreuzbandregisters am Beispiel der Sportklinik des Centre Hospitalier Luxemburg

*The Clinical and Scientific Impact of an Institutional ACL Registry: Luxembourgish Experience*

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### Methode und eingeschlossene Literatur

In unserer Einrichtung wurde 2011 ein standardisierter klinischer Behandlungspfad mit einer angeschlossenen Datenbank für Verletzungen des vorderen Kreuzbandes (VKB) entwickelt, um Patienten-, Verletzungs- und medizinische Profile bei operativer ebenso wie konservativer Behandlung dieser Verletzungen systematisch zu erfassen. Dieser Artikel beschreibt die luxemburgischen Erfahrungen mit dem hausinternen VKB-Register. Neben der Organisation des Registers werden die wichtigsten Erkenntnisse aus den Publikationsergebnissen der erfassten Daten zusammengefasst.

### Ergebnisse und Diskussion

In dem zehnjährigen Erhebungszeitraum wurden 2224 VKB-Verletzungen von 2073 Patienten in das Register eingetragen. Der standardisierte klinische Pfad ermöglichte es, epidemiologische, physiologische und pathologische Eigenschaften von Patienten zu erfassen und therapeutische Trends über die Jahre hinweg zu erkennen. Insgesamt wurden bisher 20 Artikel mit Daten aus dem Register veröffentlicht. Es konnte gezeigt werden, dass isolierte VKB-Verletzungen in der Minderzahl sind und bei einem sehr breiten Spektrum an Patienten ein personalisierter medizinischer Ansatz erforderlich ist. Unsere Erkenntnisse zu individuellen Patientenprofilen, begleitenden Weichteilschäden wie Meniskusverletzungen sowie Faktoren, die im Laufe der Zeit zur möglichen Dekompensation der Kniegelenkslaxität beitragen, gehören zu den wichtigsten Erkenntnissen des letzten Jahrzehnts. Andere Ergebnisse umfassen die Häufigkeit von VKB-Verletzungen in Mannschaftssportarten und die hohe Varianz der Kniemorphologie sowie Beiträge zum Verständnis des Behandlungsverlaufs von Patienten mit VKB-Rekonstruktion und Bewegungsanalysen. Die Erkenntnisse sind ebenfalls von großer Bedeutung, um einen hohen Standard in der Patientenversorgung zu erreichen und den kontinuierlichen Fortschritt der Kniechirurgie zu gewährleisten.

### Was ist neu und relevant?

Dieser Artikel bietet einen umfangreichen Einblick in die Organisation und die klinischen und wissenschaftlichen Möglichkeiten eines hausinternen VKB-Registers. Die standardisierte und institutionalisierte Datenerhebung vermittelt ein umfassendes Bild des Patienten, der Verletzung und der klinischen Profile.

### Methodische Einschränkungen

Die Datenerhebung des Registers ist limitiert und bietet Spielraum für Verbesserungen, insbesondere bezüglich operativer Komplikationen und der Rehabilitation. Da die Datenerfassung nur in einem Therapiezentrum erfolgt, bleibt die Therapietreue und Compliance der Patienten eine wesentliche Einschränkung dieses Registers.

### Fazit für die Praxis

#### Fakt 1

Das VKB-Register liefert ein umfassendes Bild der Patientenmerkmale, der Verletzungsmuster, der Therapieverfahren und der damit verbundenen klinischen Profile.

#### Fakt 2

Der klinische Behandlungspfad ermöglicht ein hohes Maß an Qualitätskontrolle und Standardisierung der Patientenversorgung sowie hochwertige wissenschaftliche Forschung.

#### Fakt 3

Die interdisziplinäre Zusammenarbeit sichert die interne Validität und Konsistenz der Daten, stellt jedoch auch eine große Herausforderung dar. ■



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