Graft Rupture and Failure After ACL Reconstruction

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44.1 Introduction

Although anterior cruciate (ACL) reconstruction is generally regarded as a successful procedure with an overall 81 % rate of return to sport [6], graft rupture and graft failure are not infrequent. In a systematic review, Wright et al. found a pooled graft rupture rate of 5.8 % at a minimum of 5-year follow-up [68]. A similar graft rupture rate of 4.5 % was reported by Webster et al. at a mean 4.8 years follow-up [65]. Reinjury and graft failure are potentially devastating for the patient and it is therefore important to understand the causes and risk factors of both entities.

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44.1.1 Terminology

The terms "graft rupture" and "graft failure" are frequently used interchangeably. Graft failure is a somewhat nonspecific term. It may be used to include graft rupture, graft insufficiency that may or may not be symptomatic or failure of the ACL reconstruction to provide the desired level of function. Indeed, there is considerable overlap of each of these scenarios. However, for the purposes of this chapter, graft failure will be used as a generic term to include all three.

Graft rupture will be used to refer to a traumatic rupture of a previously well-functioning ACL graft. Even so, graft rupture may still be contributed to by a poorly performed ACL reconstruction. For instance, a graft that is impinging in the intercondylar notch due to an excessively anterior placement of the femoral tunnel may, in a sense, be "doomed" from the outset and susceptible to disruption under minimal load. Thus, perceived trauma may play only a small role in the failure of such a graft.

On the other hand, early graft failure – for instance, due to poor control of rotatory laxity of the knee as a result of poor tunnel placement – may prevent the patient from returning to a high activity level because of giving way episodes, which may be perceived as traumatic. To complicate things even further, a patient may function satisfactorily despite significant graft laxity

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being present on examination or an MRI demonstrating a graft rupture. This may be particularly so in the setting of osteoarthritic change.

44.1.2 Causes of Failure Versus Risk Factors

It is worth distinguishing between causes of graft failure and risk factors for reinjury. The cause of graft failure may be able to be determined preoperatively, but findings at revision surgery may also help explain the failure. Graft failure is often multifactorial in aetiology, but at times no obvious cause for failure can be identified. Risk factors for reinjury on the other hand are factors that have been shown to have an association with an increased rate of reinjury, without there being any compromise of the ACL graft.

Understanding causes of graft failure helps the surgeon address them at revision surgery. Identification of risk factors, especially those that are potentially modifiable, is important in reducing further reinjury. Identified risk factors may not only result in modification of revision surgery but also influence the fundamental advice given to the patient about return to sport and the criteria that need to be met for progression during rehabilitation.

44.1.3 Classification of Causes of Graft Failure

In broad terms, the causes of failure can be classified as traumatic, technical and patient related. Within each category there are many individual factors that may coexist. In a study of findings at the time of ACL revision surgery by members of the French Arthroscopic Society, technical errors accounted for two-thirds of ACL graft failures, with trauma accounting for most of the rest [59]. The single most common cause of failure was femoral tunnel malposition. Causes of graft failure are discussed in detail later in this chapter.

As mentioned earlier, the role of trauma in graft failure can be difficult to determine. Putting an unstable knee under load may result in giving way, which is perceived by the patient as a traumatic episode, even though the graft may have already failed before this. It is therefore important to establish the level of function that had been achieved prior to the knee giving way.

The term "patient-related factors" encompasses many entities including generalised ligamentous laxity and associated injuries that may compromise the stability of the knee. The latter may include other ligamentous injuries that have not been adequately addressed, meniscal pathology or meniscal resection and perhaps chondral and osteochondral lesions. Other local factors include failure of incorporation and biological failure of the graft.

44.2 Risk Factors for Graft Failure (See Table 44.1)

44.2.1 Graft Type

44.2.1.1 Autograft Versus Allograft

There has been much literature about the risk for graft rupture with autograft compared to allograft use, and a number of systematic reviews with meta-analyses have been published [11, 17, 31, 32]. These reviews have compared patellar tendon autografts with patellar tendon allografts with mixed findings. An early review by Krych et al. [32] reported that allograft patients were five times more likely to rupture their grafts than patients with autografts. However, this difference was not present when irradiated or chemically treated grafts were excluded from the analysis. Subsequent reviews by Carey et al. [11] and Foster et al. [17] did not find significant differences in graft rupture rates between allografts and autografts. A more recent review by Kraeutler et al. [31] which included 3,013 autograft patients and 604 allograft patients reported an overall graft rupture rate of 4.3 % for the autograft group and 12.7 % for the allograft group. This was significantly different and demonstrated a threefold increase in graft rupture rates for allografts compared to autografts.

The above reviews do not, however, stratify for potentially important reinjury factors such as

Table 44.1 Potential risk factors for ACL graft failure

Risk factor	Comment
Graft type	
Autograft vs. allograft	Patellar tendon (PT) allografts probably have a higher failure rate than PT autografts in young patients
Hamstring vs. patellar tendon autograft	Evidence is conflicting. Registry data suggests slightly higher failure rate with hamstring grafts, but most other studies showing no difference
Graft size	Smaller graft diameter has only been shown to be a relatively small risk factor in two studies, with more studies show no effect
Age	Younger age at surgery is a strong risk factor, particularly less than 20 years old. The reasons for this are unclear
Return to sport	A return to cutting and pivoting sports is a risk factor for further injury
Early return to sport	The small amount of data available shows conflicting results
Contact vs. noncontact injury	Initial contact injury associated with higher rates of reinjury, but this may reflect the type of sport played
Biomechanics	Deficits in hip rotational control, excessive valgus, knee flexor deficits and postural control deficits are associated with increased risk of reinjury
Gender	No clear evidence to support an effect of gender
Height and weight	Increased BMI has not been shown to a risk factor for reinjury
Family history	A positive family history has been shown to a risk factor for reinjury, but it is unclear whether this is a genetic or environmental factor
Tibial slope	Although this has not been extensively investigated, studies from one centre show that increased posterior tibial slope is a risk factor for reinjury
Tunnel position	Hard to assess because of changing views of what constitutes ideal tunnel position. A more vertical alignment has been shown to be a risk factor in one centre

age or activity level. A number of studies have suggested that the failure rate of patellar tendon allografts may be greater than patellar tendon autografts in young patients. In patients 18 or younger, Ellis et al. [14] reported a revision rate of 35 % with allografts compared to only 3 % for autografts. Barrett et al. [7] also found a higher failure rate in high activity patients with an allograft compared to low-activity patients. A recently published review by Wasserstein et al. [62] specifically investigated failure rates between allografts and autografts in young active patients. Graft sources included quadrupled hamstring autografts (463 patients), patellar tendon autografts (325 patients) and various allografts (228 patients). The failure rates for hamstring autografts, patellar tendon autografts and allografts were 9.5 %, 9.8 % and 25 %, respectively. The failure rate for allografts was significantly greater than for both autografts in combination and alone. Overall, this review concluded that allografts perform poorly in young active patients.

44.2.1.2 Hamstring Autograft Versus Patellar Tendon Autograft

A number of studies by the same group have consistently shown no significant differences in rates of ACL graft rupture between hamstring and patellar tendon autografts [8, 9, 35, 51, 53]. As the participants in these studies were derived from two consecutive cohorts, the groups were mixed in regard to activity level. However, a large cohort study of 298 competitive athletes also showed no significant difference between graft rupture rates when hamstring and patellar tendon autografts were compared [34]. Recent data from the MOON cohort similarly shows no difference in the rates of revision surgery between hamstring and patellar tendon autografts [27]. These studies are in contrast to two large registry datasets published by Maletis et al. [38] and Persson et al. [50] which reported hamstring grafts to have a significantly higher risk (1.82 times and 2.3 times, respectively) of revision than patellar tendon grafts. As the end point for these datasets is revision surgery, the number of ruptures that occurred but were not addressed surgically is unknown.

A recently published randomised trial by Mohtadi et al. [43] compared patellar tendon and single-bundle and double-bundle hamstring tendon autografts. Significantly less traumatic reinjuries were reported in the patellar tendon group (3 %) compared to the single-bundle (11 %) and double-bundle (10 %) hamstring tendon groups. There were no between group differences for atraumatic graft failure rates. Younger age was also a significant predictor of traumatic reinjuries.

44.2.2 Graft Size

The relationship between graft diameter and subsequent graft failure has received attention after the publication by Magnussen et al. [37] which showed that small hamstring grafts were a predictor of early graft failure. However, the odds ratio (OR) for patients under 20 years undergoing revision compared to older patients (OR = 18.97) was far greater than the odds ratio for patients with smaller grafts requiring revision compared to patients with larger grafts (OR = 2.2). In patients 20 years or older, there was no difference in revision rates between those with a graft diameter greater than 8 mm and those with a graft diameter of 8 mm or less.

Park et al. [46] also showed greater graft rupture rates in patients with a graft size of less than 8 mm in a mostly nonathletic population. However, the association between graft size and rupture rate was not present when a cutoff of 7.5 mm was used instead of 8 mm. Webster et al. [65] found no relationship between graft size and rupture rates using a cutoff of 7 mm for graft diameter which is the same result as other recent studies by Kamien et al. [30] and Bourke et al. [8]. Overall, there is currently insufficient evidence to conclude that graft size is a major risk factor for graft rupture.

44.2.3 Age

There are an increasing number of cohort studies which show graft rupture or failure rates to be markedly higher in younger-aged patients. In one of the earliest and largest cohort studies to demonstrate an association between age and graft rupture, Shelbourne et al. [56] reported that the 5-year ACL rupture rate was 8.7 % for patients under 18 years, 2.6 % for 18–25-year-olds and only 1.1 % for patients older than 25. Similar rupture rates were subsequently found by Kaeding et al. [26] who reported a rate of 8.2 % for patients 10–19 years compared to a 1.8 % rupture rate in patients over 30 years.

More recent cohort studies have shown even larger discrepancies between younger and older patients. Kamien et al. [30] reported a 25 % graft failure rate in patients aged 25 years or younger compared with only 6 % for those over 25. In a cohort of top-level young athletes (NCCA Division 1 Sports), Kamath et al. [28] reported a 17.2 % rupture rate for patients who injured their ACL before entering college compared to a 1.9 % rate for those who injured their ACL whilst in college. Magnussen et al. [37] and Webster et al. [65] found similar rupture rates for patients under 20 years, with rates of 14.3 % and 13.6 %, respectively. This was notably higher than the respective 0.7 % and 2.4 % rates found in the over 20-year-old patient groups. In the longest follow-up to date, Bourke et al. [8] found that 34 % of patients who were 18 years or younger at surgery had sustained a graft rupture by 15 years compared to only 14 % who were older than 18 years. In the same cohort, young males were found to be the most susceptible with a rupture rate of 46 % at 15 years compared to 14 % in males older than 18 years.

ACL registry data has also shown age to be a risk factor for reinjury. Data from the Danish registry reported that patients younger than 20 at the time of primary surgery had a significantly higher risk (adjusted relative risk of 2.58) of revision ACL reconstruction than patients older than 20 [36]. The Norwegian ACL registry [50] similarly showed that age was a significant risk factor for revision with a hazard ratio of 4.0 for revision in the youngest age group (15–19 years) compared to the oldest (>30 years). Multiple studies from the Swedish ACL registry have been published which indicate age as a risk factor for ACL injury [2, 4, 5, 15, 33]. The most recent work [5] shows that adolescent patients (defined as 13–19 years) have the highest rates of early revision (within 2 years) with an overall incidence of 3 % compared to a less than 1 % incidence in the over 30 age group.

Data from the Kaiser Permanente ACL registry has similarly shown higher revision rates in younger patients with 32 % of all revision surgeries performed in patients 21 years of age and younger [40]. Recent data from the MOON cohort [27] has also shown that younger-aged patients have significantly increased odds for revision surgery.

When taking all the above data together, it is clear that a young age is a significant risk factor for ACL graft rupture. The reasons for this are not clear, but one contributing factor may be the participation of young people in sports that put their knees at greater risk of injury. This is explored in the next section.

44.2.4 Return to Sport

Returning to sports that involve cutting and pivoting has been shown to significantly increase the risk of graft rupture in some studies but not others. Webster et al. [65] found that a return to strenuous cutting/pivoting sports led to an almost fourfold increase in the risk of graft rupture. Salmon et al. [53] similarly showed a twofold increase in the risk of graft rupture for patients who returned to either moderate (i.e. tennis, skiing) or strenuous (i.e. football, basketball) activities. On the other hand, studies by Pinczewski et al. [51] and Kamien et al. [30] did not find a relationship between activity level and graft rupture. Park et al. [46] similarly did not find athletic status (athlete vs nonathletes) to be associated with graft rupture nor did Bourke et al. [9] find a relationship between graft rupture and return to pre-injury sport.

The different ways in which activity level has been defined make synthesis of this data challenging. Whilst the above-referenced studies look at the risk of returning to different types or levels of sport, it is relevant to note that returning to sport itself may be one of the most salient factors associated with subsequent graft injury. To illustrate this, Shelbourne et al. [56] noted that in a sample of 1,415 patients, only 6.6 % of ACL reinjuries occurred for reasons other than sport. It is also worth noting that few studies account for athletic exposure. In one that did, Paterno et al. [48] showed that the ACL injury rate was 15 times greater in people with a past ACL history compared to a control group.

Indeed, the high reinjury rates reported in younger patients may be related to a higher rate of returning to pre-injury sport in this age group. Webster et al. [65] reported that 88 % of younger patients (<20 at surgery) returned to strenuous sport following ACL reconstruction, whereas this was the case for only 53 % of patients in the over 20 group. A recent systematic review also reported that younger patients were significantly more likely to return to their pre-injury sport with the patients who had returned being on average 3 years younger than those who had not returned [6].

44.2.4.1 Early Return to Sport

There is little empirical data on whether an early return to sport is a risk factor for graft rupture. Shelbourne et al. [56] reported that over a 5-year period, patients who returned to full activity before 6 months postoperatively did not have a statistically significantly higher incidence of graft injury than patients who returned to full activity after 6 months. Laboute et al. [34] however showed that those who returned to competition within 7 months of surgery had a greater risk of reinjury than those returning later. The rupture rate was 15.3 % for those who returned early compared to 5.2 % for the later return group.

44.2.4.2 Contact vs. Noncontact Injury

Patients who sustain a contact mechanism of injury appear to be more likely to have a subsequent graft rupture than patients who have a noncontact mechanism of injury. Both Salmon et al. [53] and Webster et al. [65] showed threefold increases in the risk for graft rupture for patients whose initial ACL injury was a contact mechanism. These findings may be reflective to the types of sport played; however, the mechanism by which a contact injury worsens prognosis is unclear.

44.2.5 Biomechanics

Abnormal movement strategies when performing sports-related tasks have been identified in patients who have returned to sports after ACL reconstruction and have been suggested as another potential factor that may increase the risk of ACL reinjury [42, 47, 49, 57, 64]. A prospective cohort study by Paterno et al. [49] which examined neuromuscular and biomechanical factors for second ACL injury found four measures of asymmetry that accurately predicted second ACL injury risk. These included deficits in hip rotational control, excessive frontal plane knee mechanics, knee flexor deficits and postural control deficits [24]. This study importantly showed that abnormal movement patterns after ACL reconstruction were not isolated to the injured knee, which has implications for rehabilitation. However, within the context of this chapter, it is relevant to note that the majority of patients (77 %) in this cohort study sustained second injuries to the contralateral knee rather than sustaining a graft rupture.

44.2.6 Gender

Studies which have investigated patient sex as a risk factor for graft rupture have either shown no influence or have shown male patients, particularly younger males, to be at greater risk [8, 9, 25, 34, 35, 37, 46, 51, 53, 55, 56, 65]. Data from both the Danish [36] and Norwegian [50] ACL registries as well a data from the MOON cohort [27] report no effect of sex on the risk for ACL revision surgery. Data from the Swedish ACL registry shows higher rates of revision ACL reconstruction in young females aged 15–18 years compared with males of the same age group [1]. It is therefore reasonable to conclude that to date there is no clear-cut relationship between sex and the risk for graft rupture.

44.2.7 Height and Weight

Although an increased BMI has been shown in one study to be a risk factor for noncontact ACL injuries in females [60], the influence of height and weight has not been extensively investigated. In their study of the influence of age and graft diameter on the risk of ACL graft rupture, Magnussen et al.[37] did not find any association between the ratio of graft diameter to patient weight, height or BMI and the risk of reinjury. Similarly, Park et al. [46] did not find a correlation between graft rupture and patient weight, height or BMI. Analysis of data from the Kaiser Permanente ACL Reconstruction registry also did not demonstrate BMI to be a risk factor for revision ACL reconstruction [39].

44.2.8 Family History

Bourke et al. [9] and Webster et al. [65] both found a significant relationship between a positive family history for ACL injuries and graft rupture. In both studies having a first-degree relative who also sustained an ACL injury doubled the risk for graft rupture. Given the limited number of studies, it is difficult to draw firm conclusions about the influence a positive family history has on graft rupture. It is also difficult to know whether an association represents a true genetic risk or rather an active family lifestyle.

44.2.9 Tibial Slope

Increased posterior slope of the tibial plateau increases anterior tibial translation [20] and has been suggested as a risk factor for primary ACL injury [10]. However, the data is conflicting and has been well summarised in a systematic review [66]. Webb et al. [63] investigated posterior tibial slope of those in ACL-reconstructed patients who had a further ACL injury and found a significant association between increased tibial slope and further ACL injury, particularly in those patients who sustained both an ACL graft rupture and a contralateral ACL rupture. The mean posterior tibial slope in patients who did not sustain a further ACL injury was 8.5°. Patients with a slope of 12° had a five times increased risk of further ACL injury.

44.2.10 Tunnel Position

The influence of bone tunnel position on graft rupture is difficult to analyse as there is no universally agreed method of describing tunnel position and no clear consensus on what constitutes good tunnel position. Indeed, concepts of ideal tunnel position continue to evolve. Nonetheless, there is evidence to indicate that tunnel position is important and some examples will be provided.

In a 15-year follow-up of patients who had undergone hamstring reconstruction for an isolated ACL tear, Bourke et al.[8] found that patients who sustained a graft rupture had a significantly more posteriorly placed tibial tunnel than those who did not, whereas there was no difference in femoral tunnel position or graft inclination angle. The same group also reported [35] an association between graft rupture and nonideal tunnel position – using the previously described criteria – for both patellar tendon and hamstring grafts.

Over the past decade or so, there has been an increased tendency to drill the femoral tunnel via the anteromedial portal in an attempt to achieve a more anatomic positioning of the graft. Although Magnussen et al. [37] did not observe any difference in revision rates based on the technique used to drill the femoral tunnel, data from the Danish Knee Ligament Reconstruction Register [52] has however shown a significantly increased cumulative revision rate after 4 years for ACL reconstructions where the femoral tunnel was drilled via the anteromedial portal (5.2 %) compared to drilling via the tibial tunnel (3.2 %). Whether this reflects uptake of a new technique or greater stress being placed on a more anatomic graft is unclear.

Apart from its impact on clinical outcome and the risk of reinjury, tunnel position is also an important consideration in revision surgery and is further discussed in the following section.

44.3 Causes of Graft Failure

As mentioned earlier, the classification of causes of graft failure is difficult. Precise definitions of the potential causes are often lacking. For instance, a traumatic event is frequently cited as a cause of failure, but there is no consensus as to what constitutes a traumatic event. This is further compounded by the overlapping and multifactorial nature of the factors involved, well demonstrated in the study from the MARS group which reported a combination of causes of graft failure in 37 % of patients undergoing revision ACL reconstruction [22]. Ahn et al. [3] reported an even higher number of patients (59 %) with multiple causes for their graft failure. In addition, different authors may include the same entity in different subgroups, making synthesis of the literature difficult, or include an “unknown cause” category.

Despite these inherent difficulties and limitations, a review of the literature was undertaken to identify the reported findings at revision ACL reconstruction surgery that may explain the causes of graft failure. The results are summarised in Table 44.2, which uses the following principal categories to group the findings: new trauma, technical issues and patient-related factors.

44.3.1 New Trauma

New trauma is stated as a cause of failure for between one-third and two-thirds of patients undergoing revision ACL reconstruction, although only two papers cited it as the cause of failure in more than 50 % of patients [41, 54]. However, it is difficult to determine the actual role of the trauma when other factors are also identified.

Some authors distinguish between early (<6 months) and late failures [29, 54], with the implication being that early failures are mainly due to factors such as fixation failure and biological failure, whereas late failures are more likely to be due to trauma and tunnel malposition. However, because of the inconsistency of reporting of the time from primary surgery to injury, as well as of multiple potential causes of failure, it is difficult to draw any conclusions about this.

44.3.2 Technical Issues

Technical issues that may have contributed to ACL graft failure are typically identified in

Table 44.2 Summary of causes of failure (blank cell indicates no data provided; because multiple causes of failure may coexist, percentages may add up to more than 100)

		Technical error							Patient related				
		Tunnel malposition											
	New trauma	Femoral	Tibial	Both	Not specified	Fixation failure	Prosthetic graft failure	Not specified	Biological or Unknown	Infection	Instability or hyperlaxity	Tunnel widening	Malalignment
Ahn et al. [3]	18 %	34 %	20 %	39 %					16 %		5 %		
Denti et al. [12]	35 %						10 %	42 %	3 %				
Diamantopoulos et al. [13]	24 %			63 %			6 %		2 %		3 %	2 %	
Ferreti et al. [16]	47 %				33 %		13 %		7 %				
Garofalo et al. [18]		79 %											
Grossman et al. [21]	48 %							35 %	17 %				
Lind et al. [36]	38 %	20 %	6 %						24 %	2 %	3 %	2 %	
Mars Group et al. [22]	32 %	49 %	23 %			4 %			7 %		2 %		3 %
Mayr et al. [41]	56 %			32 %									
Salmon et al. [54]	65 %				22 %	2 %			11 %				
Trojani et al. [59]	30 %	36 %	11 %			5 %			15 %	2 %	9 %		
Wright et al. [68]	49 %							46 %	5 %				

one-third of patients undergoing revision ACL reconstruction, although Salmon et al. reported technical issues in only 24 %, but this was a single surgeon series. On the other hand, in a large multicentre study the MARS group identified technical issues in 53 %. Some of the more frequent technical issues are discussed below.

44.3.2.1 Tunnel Malposition

Although a number of papers describe their technique of evaluation of tunnel position on plain radiographs [18, 29, 54, 58, 59], methods and threshold values vary between studies. In addition, significant intra-observer and interobserver variability has been reported [61]. Defining tunnel malposition at the time of surgery is even more subjective, with no reliable criteria having been reported. It should also be recognised that concepts of ideal tunnel position have changed during the two decades in which the relevant studies have been published.

Femoral tunnel malposition is the most frequently identified technical issue. In a small series, Garofalo et al. [18] reported that 79 % of femoral tunnels were too anteriorly positioned. The MARS Group [22] found that 48 % patients undergoing revision ACL reconstruction had malpositioned femoral tunnels, whilst Trojani et al. [59] reported 36 %. In a later report from the MARS Group [44] that focused specifically on femoral tunnel position, femoral tunnel malposition alone accounted for 25 % of failures. When combined with other causes, it accounted for up to 48 %. The most common errors were too vertical (36 %), too anterior (30 %) or both (27 %).

Tibial malposition is less frequent than femoral tunnel malposition and is often reported in combination with femoral tunnel malposition or other causative factors. Isolated tibial tunnel malposition was reported in 20 %, 11 % and 6 % by Ahn et al. [3], the report of a French multicentre study [59] and a report for the Danish register for knee ligament reconstruction [36].

44.3.2.2 Fixation Failure

As with tunnel malposition, fixation failure can be hard to define. Whilst it may be possible to identify complete loss of fixation, identification of fixation failure that allows for minor slippage of the graft within a bone tunnel requires specific research tools such as radiostereometric analysis, which is beyond the scope of the reported studies evaluating causes of failure leading to revision. Nonetheless, fixation failure appears to be an uncommon cause of ACL graft failure with rates of 2 %, 4 % and 5 % being reported by Salmon et al. [54], the MARS group [22] and Trojani et al. [59], respectively.

44.3.3 Patient-Related Factors

44.3.3.1 Biological Failure

The concept of biologic failure remains poorly defined. George et al. [19] included immunological response, over-tensioning and infection under this heading, whilst Harner et al. [23] also included aggressive rehabilitation. Except for infection, there is no direct evidence, particularly at the time of revision surgery, that these are causes of graft failure. Denti et al. [12] defined biological failure as when “the patient did not experience a trauma, and the graft appeared well positioned on imaging and arthroscopy” and reported a rate of 3 %. In their systematic review, Wright et al. [67] reported a similar low rate of 5 % for failure of the primary reconstruction due to a “biological cause”. Interestingly the Danish knee ligament register study shows 24 % incidence of unknown causes but makes no reference to biological failure [36].

Infection can be considered as a cause of failure in its own right or as a subcategory of biological causes. It is infrequently reported as a cause of failure and when reported has a low incidence of 2 % [36, 59].

44.3.3.2 Associated Ligamentous Pathology

Like many other potential causative factors, associated ligamentous pathology is difficult to define and may well exist in combination with other factors. Trojani et al. [59] found untreated laxity in 5 % and generalised ligamentous laxity in 4 % of patients undergoing revision ACL reconstruction. The MARS group reported posteromedial and posterolateral laxity as a causative factor in 2 % of a similar group of patients [22]. In contrast, Noyes et al. reported that 44 % of patients undergoing revision ACL reconstruction with a patellar tendon allograft required additional surgery for associated ligamentous laxity, particularly on the lateral side [45]. However, the overall reporting of associated ligamentous pathology as a cause of ACL graft failure is low [29].

44.3.3.3 Limb Malalignment

Limb alignment can affect stability at the knee. When increased varus or valgus at the knee is present, it may exacerbate the effect of collateral instability. However, limb malalignment is rarely reported as a cause of ACL graft failure [45]. The MARS group identified limb malalignment as a causative factor for failure in only 3 % of patients undergoing revision ACL reconstruction [22].

Conclusion

Graft failure includes graft rupture, graft insufficiency that may or may not be symptomatic and failure of the ACL reconstruction to provide the desired level of function. Graft failure is often multifactorial in aetiology, and there are also identified risk factors for reinjury.

A young age is a significant risk factor for ACL graft rupture. The reasons for this are not clear, but one contributing factor may be a higher rate of returning to pre-injury sport in this age group. Despite anecdotal examples, there is little empirical data on whether an early return to sport is a risk factor for graft rupture.

Whilst allografts have been shown to perform poorly in young active patients, there is no consistent data to suggest a difference in reinjury rates between the two most common autografts, hamstring tendon and patellar tendon. Similarly there is currently insufficient evidence to conclude that graft size is a major risk factor for graft rupture.

There is no clear-cut relationship between gender and the risk of graft rupture and BMI does not appear to be a risk factor for revision ACL reconstruction. However, there is some evidence to indicate that patients with an increased posterior tibial slope have an increased risk of further ACL injury.

Analysis of patients undergoing revision ACL reconstruction has shown that the two most frequently cited causes of graft failure are a further episode of trauma and technical issues. However, there are often a number of potential causes identified in the same patient. Of the technical issues, femoral tunnel malposition is the most frequently identified. Tibial malposition is less frequent than femoral tunnel malposition and is often reported in combination with femoral tunnel malposition. Fixation failure appears to be an uncommon cause of ACL graft failure. Patient-related issues are infrequently cited as a cause of failure, but include so-called biological failure, associated ligamentous pathology and limb malalignment.

Overall, understanding the role that a young age plays in increasing the risk of graft failure and eliminating technical issues, particularly femoral tunnel malposition, appear to be the two most important strategies in reducing the risk of ACL graft failure.

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