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Current Etiologies and Modes of Failure in Total Knee Arthroplasty Revision

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Although total knee arthroplasty is a very effective intervention and increasing in prevalence, failures do occur. We studied patients presenting for total knee arthroplasty revision to determine any modifiable causes of failure, both short and long term, and where future efforts should be directed to reduce the incidence of failure. A multicenter prospective observational cohort study of 318 consecutive patients, with minimum 1 year follow-up, undergoing total knee arthroplasty revision was performed. Associations between modes of failure were also assessed. The mean time from primary procedure to total knee arthroplasty revision was 7.9 years. Many patients (64.4%) had more than one cause of failure. Thirty-one percent of patients were early (< 2 years) failures at a mean of 11 months. These had a higher prevalence of infection, perioperative factors and comorbidities. Late failures occurred at a mean of 119.2 months. Other major causes of failure included instability (28.9%), wear (24.5%) and component loosening suggesting the importance of modifications in technique, implants and other areas. Application of these findings will ultimately reduce revision numbers through continued refinement of total knee arthroplasty practice and through further specific investigation of these modes of failure.

Level of Evidence: Therapeutic study, level II-2 (prospective study). See the Guidelines for Authors for a complete description of levels of evidence.

The clinical and economic effectiveness of total knee arthroplasty (TKA) in alleviating the adverse consequences of knee arthritis has been widely recognized.[19] The 10–15 year implant survivorship is routinely greater than 90%.[9,22] This effectiveness is reflected in the increasing numbers of these procedures being performed. An estimated 321,084 TKAs (an increase of 5% compared with 2001) and 32,159 TKA revisions (TKAR) (an increase of approximately 7.5%) were performed in the United States in 2002.[19] These numbers are expected to more than double by 2030, with revision surgery expected to increase as more primary surgeries are performed.[1,8]

It is generally accepted TKAR is a more complex procedure than primary TKA, and the results have been less successful than for primary TKA.[28] Total knee arthroplasty revisions consume more health care resources at each clinical stage because of the increased technical demands (implants and allografts), length of hospital stay, higher complication rates, and a lengthier period of convalescence.[26] The estimated cost of a TKAR is approximately double than the primary procedure.[14,20]

Although less than 3% of all TKAs performed require revision in the first 2 years postoperatively,[15] over longer periods of followup and with the large numbers of TKA now being performed, the absolute numbers potentially requiring revision increase. Others have reported up to 64% of TKARs will take place within 5 years of the index procedure.[11] It is clear there are differences between early and late failures in TKA,[30] and therefore it is also likely associated or predisposing factors to these failures will also differ. Better understanding of the current causes of TKA failure and how they interact is important in identifying specific areas for improvement and populations at particular risk.

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We prospectively studied TKAR patients to ascertain whether we could identify modifiable patient-related or technical factors that might decrease the incidence of revision. We considered both short and long term modes of failure. We also intended to to determine the most important factors surgeons should consider at time of primary TKA and to identify those factors in need of further study.

MATERIALS AND METHODS

We conducted a multicenter, prospective, and observational cohort of a consecutive series of patients with failed TKAs who were deemed candidates for revision surgery. Institutional review board approval was obtained at each participating site. Once the need for TKAR was determined all patients at each center were then assessed and consented for inclusion according to specific inclusion and exclusion criteria (Tables 1 & 2).

Three hundred eighteen patients were ultimately recruited, with a minimum follow-up period of 1 year (Table 3). The mean age of the cohort was 68.7 years (range 34 to 85 years). Mean BMI for male patients was 30.8, and for women patients was 33.1. The mean time from primary procedure to TKAR for the whole group was 7.9 years (range, 6 months to 27 years).

The primary research question was addressed by collecting specific information on the modes of failure and other factors affecting surgery (Table 4), time until failure for primary implants, and comorbidities. We subdivided the time to failure of the primary TKA, according to previous published criteria, into short-term failures (occurring after < 2 years) and long-term failures (occurring ≥ 2 years).[30] The modes of failure for the primary TKA were not mutually exclusive; allowance was made for recording more than one cause of failure. We made a distinction between polyethylene wear and polyethylene failure, with the latter indicating catastrophic failure or actual breakage of the insert (Table 4). We also recorded characteristics of the patients' baseline knee examination (Table 5).

All collected data were analyzed using descriptive statistics, and the comparison of early and late groups in terms of numbers failing due to sepsis was performed using a Chi Square test.

TABLE 1. Inclusion Criteria for NAKAR Study

1. At the least, the tibial and/or the femoral component required reconstruction
2. Signed informed consent was obtained
3. The patient was > 18 years
4. The patient was cognitively intact, fluent in English, and capable of completing the self administered questionnaires, and adhered to the study protocol
5. The patient had a primary total knee arthroplasty that had failed (and not a rerevision)

NAKAR = North American Knee Arthroplasty Revision

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TABLE 2. Exclusion Criteria for NAKAR Study

1. Rerevision total knee arthroplasty
2. Failed unicondylar prostheses
3. Total knee arthroplasty in need of only a polyethylene exchange
4. Metastatic or primary tumor of the knee
5. Reflex sympathetic dystrophy of the affected knee
6. Patient is medically unsafe to undergo the procedure as judged by the coinvestigator
7. Progressive muscular condition, causing deterioration of the quadriceps muscle
8. Neurologic deficit impairing the affected limb
9. Knee pain associated with back pathology such as spinal stenosis or vascular occlusion
10. Patient declined participation

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RESULTS

The majority of patients (64.4%) exhibited more than one cause of failure. Arthroplasty failure was classified as aseptic in 262 cases (82.4%) and septic in 56 cases (17.6%). Surgeons reported the tibia needed revision in 78% of the cases, the femur in 71% of the cases, and the

TABLE 3. Cohort Demographics

Demographic Groups	Subgroups	Percentage
Gender	Male	47
	Female	53
Race	White	83
	African American	14
	Other	3
Marital status	Married	61
	Widowed	19
	Divorced/separated	11
	Single (never married)	7
	Living with a significant other	2
Caregiver	Present	72
	Absent	28
Public programs	Marked one	
	Social Security	39
	Disability	31
	Workers Compensation	22
	Not in any programs	8
	Marked more than one	
	Social security & disability programs	82
	All 3 programs	48
	Others	7

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TABLE 4. Reasons for Knee Arthroplasty Failure/Revision

Reason for Revision	Percent
Instability	28.9
Polyethylene wear	24.5
Failed polyethylene insert	18.1
Infection	10.4
Extensor mechanism instability	1.3
Implant loosening/migration	
Tibial	22.2
Femoral	14.1
Patellar	5
Bone lysis	
Tibial	27.5
Femoral	22.5
Patellar	9.4
Malalignment	9.4
Implant breakage	3.4
Metal wear	2.7
Ingrowth bead shedding	0.7
Ingrowth pad dissociation	0.3
Breakage of wires/screws	0.3
Modular component dissociation	0.3

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patella in 31% of the cases. The main reasons reported for failure included instability, tibial bone lysis, polyethylene wear, femoral bone lysis and tibial loosening (Table 4). Surgeons reported the tibia needed revision in 78% of the cases, the femur in 71% of the cases, while the patella needed revision only in 31% of the cases. The mean tibiofemoral angle in failed TKAs was 3° of varus (Table 5).

TABLE 5. Clinical Assessment of Knees at Baseline

Clinical Assessments	Direction of Movement	Degree	
Mean tibiofemoral	—	3° ± 8°	
Mean range of motion	Flexion	95° ± 21°	
	Extension	3° ± 8°	
		Percentages	
Knee Stability	Status of Ligament/Tendon	*Unstable*	*Stable*
Anterior/posterior instability	—	41.6	58.4
Varus/vulgus instability	—	51.3	48.7
Medical collateral ligament	Intact	72.5	
	Attenuated	16.4	
	Absent	3	
Lateral collateral ligament	Intact	75.5	
	Attenuated	12.1	
	Absent	1	
Extensor mechanism	Intact	95.9	
	Disrupted	2.7	

The mean range of motion (ROM) was 95° for flexion and 3° for extension. The extensor mechanism was intact in 97 % of cases.

Late modes of failure predominated, with 31% of the total cohort in the short-term failure group and 69% in the late failure group. The mean time to failure for the short-term group was 11 months (± 6.37 months). This group contained more ($p < 0.0001$) cases of septic failures (25.4%) than did the long-term failure group (6.9%). Sepsis was present in 17.6% of the total cohort and the average interval to revision for the septic group overall was 2.5 years. When comorbid conditions were considered, 20% of patients with septic failure had diabetes mellitus and 13.7% had rheumatoid arthritis, although these did not differ markedly from the overall cohort. The late failure group failed at a mean 119.20 months (± 63.01 months), and had more failures from polyethylene wear, instability, femoral loosening, and osteolysis than the short-term group.

Several potentially modifiable modes of failure were identified. First, polyethylene wear was typically a late mode of failure and was associated with a mean interval to revision of 11 years, with only a 5.9% early revision rate. Of the patients with wear, a large percentage (44%) had concomitant instability, whereas only 9.6% simultaneously had malalignment and wear as modes of failure. The next major modifiable cause found was instability, with an average interval to failure of 8.4±6.0 years, and with 80% of these patients being in the late failure group. Instability was present in the anterior-posterior plane in 41.6 % of cases and in the coronal plane in just over half of cases, and was associated with either femoral or tibial component loosening in 29.1% of cases. The medial collateral ligament was intact in 72.5% of the cases, and the lateral collateral ligament was intact in 75.5% of the cases. Only a small percentage of the overall cohort had malalignment of any of the components (9.4%), but of those that did, 60% had concomitant instability. Loosening may represent an end point of different modes of failure, and thus may not always be modifiable in isolation, but associations with other modes were demonstrated here. The average duration to failure for loosening was just over 9 years, with tibial implants more likely to loosen than femoral or patellar components. Fifty-five out of our 65 cases that had tibial loosening had a cemented primary component. More than half of patients with loose implants had concomitant osteolysis, 25% had instability, and only 8.9% of patients had implant malalignment.

DISCUSSION

As the number of knee arthroplasty procedures increases[1,8] it is essential to continually analyze the causes and timing

of failure and to identify what modes of failure can be addressed by modifications to implants or techniques. It is recognized that failures can be divided into early and late groups and this is useful in terms of understanding the etiology of each and devising approaches to minimize the numbers in both groups. Our main aim was to establish, by means of a prospective study of TKAR patients, potentially modifiable factors in cases of TKA failure and their interactions. We also wished to assess how short term modes of failure currently differ from long term and to identify particular areas in need of further study.

Although our study was designed to record a consecutive series of patients with failed TKA, the decision as to whether revision was required was ultimately a subjective one based on the assessment of the participating surgeons. It should be noted, therefore, that potential bias could enter the process when deciding on revision or not. For example, in cases of pain of uncertain origin or stiffness, or selection criteria, although an attempt to give a homogeneous cohort of TKA failures has omitted cases of, for example, isolated polyethylene exchange. Nevertheless, apart from these potentially controversial indications for revision, this study does represent the great majority of revision cases that are currently presenting. A further potential shortcoming of the study is that it only includes failed TKA and not the denominator population of all primary procedures from which these failures are derived. This limits the possible conclusions that can be drawn from some of the findings, as will be discussed further.

The average interval to failure here of 7.9 years appears longer than typically reported in earlier papers (Table 6). Although a longer interval to failure is an apparently positive finding, the relative lack of comparability between reports in the literature renders it difficult to extrapolate definite conclusions from this observation. The main potentially modifiable causes of failure were infection, instability, loosening, and polyethylene wear, which reflected trends in previous studies.[10,31,32] At least two coexisting reasons for failure were identified in ⅔ of the patients, an expected finding because the different modes of failure may be interrelated.[16] The proportions of patients in early and late failure groups here, 31% percent in the former and 69% in the latter, are quite different than those described by Sharkey et al (Table 6).[30] However, Sharkey et al reported the early and late failure groups failed at an average of 1.1 years and 7 years, relatively similar to our findings of 11 months and 9.9 years for these groups respectively.[30]

The incidence of sepsis was the most marked difference between short term and long term failure groups, reflecting previous reports on TKAR.[30] Sepsis occurred in 17.6% of the total cohort, with 25.4% of the early revision group failing because of infection as opposed to 6.9% in the late group. Septic failures have a less successful outcome after

TABLE 6. Data from Selected Papers on TKA Failure

Paper	Patient Number	Follow-up	Number Failed	Average Time to Failure	Ratio Early: Late	Ratio Aseptic: Septic	Loosening	Instability	Ligament Imbalance	Polyethylene Wear	Patellar Complications
Ahlberg A[2]											
RR	254	—	31 (12%)	3.9 years	NS	31:7	14 (45.2%)	—	—	—	30 (0.9%)
Cameron H[7]											
RR	700	—	94 (13.4%)	4.7 years	NS	75:19	39 (41.5%)	5 (4.7%)	7 (6.6%)	6 (5.6%)	9 (8.5)
Fehring TK[12]											
RR	440	5 years	440 (100%)	—	279:161*	174:105	45 (10.2%)	74 (27%)	—	21 (7%)	22 (8%)
Sharkey P[30]											
RR	212	—	212 (100%)	3.7 years	118:94	175:37	51 (24.1%)	45 (21.2%)	25 (11.8%)	53 (25%)	11 (5.1%)
Current paper											
PS	318	1 year	318 (100%)	7.9 years	99:219	262:56	141 (41.3%)	96 (30.2%)	—	78 (24.5%)	20 (6.3)

Where percentages were not provided in studies we have approximated percentages to facilitate comparisons
RR: retrospective review
PA: prospective study
NS: not specified
*Study designed to focus on early failures

revision than aseptic failures, emphasizing the importance of attempting to minimize the incidence of infection.[3,17,18,29,31,33] Although somewhat unpredictable, sepsis can represent a potentially modifiable cause of failure in certain patients and situations. Our findings of early infection suggest a largely perioperative etiology of infection and emphasize the need for ongoing critical review of intraoperative sterility and techniques. Also, aggressive management of postoperative wound problems known to be associated with later infection such as persistent drainage, delayed healing, or hematoma formation is underscored by these findings.[5,13,27] Even though we do not know the numbers of patients with diabetes mellitus and rheumatoid arthritis included in the denominator primary TKA population of our cohort, the numbers of patients with these conditions who failed because of infection here were relatively high. TT This supports previous reports that these conditions predispose patients to postoperative infections, and emphasizes the need for extra vigilance in managing these patients.[21,24] This group may also potentially benefit from the routine use of cement containing antibiotics.[6]

One of the predominant modes of failure was instability, which was present in the anterior-posterior plane in 41% of patients, and in the coronal plane in more than half of patients, a slightly higher incidence of instability than reported in previous studies.[4,7,23,30] Instability was predominantly a late mode of failure, indicating factors other than acute technical issues are also involved. From the results, these include excessive polyethylene wear (in 44% of instability cases), implant loosening/migration (in 29.1% of instability cases), or late ligamentous failure. Although others have also found instability to be a substantial cause of late failure, our level of early instability is still relatively small.[30] It is nevertheless true that in order to prevent instability in TKA, correct ligament tensioning and balance, component size and design, and alignment are all essential.[12,30] The last point is emphasized by our finding that although only a small percentage of the overall cohort had malalignment of any of the components (9.4%), of those that did, 60% had concomitant instability.

The other main categories in late failures were loosening, wear and, to a lesser extent, malalignment. There were some noteworthy relationships between the etiologies that were in contrast to previous reports. For example, only 8.9% of patients with loosening had implant malalignment, in contrast with findings of 44 % malalignment with loosening in a previous study.[30] Furthermore, although some studies have shown poorer results with uncemented fixation,[10,30] 55 out of our 65 cases that had tibial loosening had a cemented primary component. However, the lack of a denominator population precludes a definitive conclusion regarding the effects of fixation on this cohort. The average duration to failure was just more than 9 years for the three types (femoral, tibial and/or patellar) of component loosening. Consistent with past studies, tibial implants were more likely to loosen than femoral or patellar components (excluding past experience with metal backed patellar components).[4,24,25,33] More than half of patients with loose implants had concomitant osteolysis, and 25% also had instability. The mean interval to revision for polyethylene wear was 11 years, with only a 5.9% early revision rate. We found component alignment was possibly not a critical etiological factor in wear related failure as only 9.6% had malalignment and wear as simultaneous modes of failure. However, as reported by Sharkey et al, assessment of wear was based on gross inspection and may have missed situations where backside wear was a factor.[30]

In conclusion, it is clear there remain several potentially modifiable and interrelated modes of failure in TKA that differ between the short and long term, and we have identified certain areas that may benefit from further refinement and modification. Further study is required regarding the influence of patient factors such as diabetes or rheumatoid arthritis and technical factors such as implant type, fixation and design. Greater definition of the interrelationships between the different modes of failure will also contribute to prevention of failure and management strategies. Dedicated studies and, increasingly, registry derived data, will improve our understanding of and ability to modify modes of failure, thus improving outcomes for TKA patients.

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