Critical Rehabilitation for Partial and Total Knee Arthroplasty

Guidelines and Objective Testing to Allow Return to Physical Function, Recreational and Sports Activities

Frank R. Noyes
Sue Barber-Westin
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Editors
Frank R. Noyes
Cincinnati Sportsmedicine and Orthopedic Center
Noyes Knee Institute
Cincinnati, OH
USA

Sue Barber-Westin
Noyes Knee Institute
Cincinnati, OH
USA

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Preface

The successful treatment of patients undergoing partial and total knee replacements has multiple facets that require careful planning and strict compliance of issues that span the entire program. These include preoperative assessments, understanding patient goals and individual issues, and technical operative details. Most important, and the major topic of this book, is the postoperative rehabilitation program that successfully restores knee motion, function, strength, and return to daily and recreational activities.

Many younger, athletic patients that undergo knee replacement have a strong desire to resume an active lifestyle after surgery. This places a sometimes daunting responsibility on the clinical team to design and implement rehabilitation protocols that allow a higher level of activities postoperatively. The task of setting realistic patient goals and expectations in younger patients who expect to have nearly normal knee function may be difficult, even with the best of operative outcomes.

Complicating matters is the fact that these individuals commonly delay surgery for a few years due to arthritis-induced symptoms. They typically present with muscle atrophy and altered limb function encompassing all muscle groups of the hip and lower extremity. Preoperative rehabilitation may be required to improve muscle strength and function, and evidence of the effectiveness of such programs is described in this book.

It is interesting to note from a historical standpoint that published knee replacement rehabilitation programs commonly failed to provide parameters for return to athletic activities. They lacked an emphasis on individual assessments, objective methods to determine function and strength, and outcome instruments that specifically detailed the return to recreational and athletic pursuits. A similar observation existed for rehabilitation and return to sports protocols after athletic knee injuries that underwent extensive changes in the past decade [1]. At our Knee Institute, there is very little difference in the entire rehabilitation program for treatment of both sports injuries and knee replacements. Our extensive clinical experience has shown that patients who desire to return to recreational sports after knee replacement need more robust and advanced programs.

The majority of published knee replacement rehabilitation protocols often discharge all patients 12 weeks after surgery. This book emphasizes the need for extended rehabilitation to completely restore lower limb function, strength, and coordination parameters for patient who desire to resume recreational and athletic activities. Individualized programs to match patient goals and recreational pursuits, detailed in several chapters, may require up to 12 months to achieve a high degree of success and patient satisfaction. Gone are the days when patients are discharged from therapy just a few months postoperatively who are barely recovered and still harbor extensive muscle disuse and poor function due to surgery and prior inactivity.

We wish to thank all of the authors of *Critical Rehabilitation for Partial and Total Knee Replacement* whose contributions provide the successful aspects they have implemented in the monitoring and structure of rehabilitation programs. This knowledge base should assist patient clinics worldwide in implementing these strategies into their own postoperative programs. The advanced rehabilitation concepts detailed in this book will help achieve a high level of patient satisfaction for the achievement of an active lifestyle following knee replacement surgery.

Cincinnati, OH, USA — Frank R. Noyes
Cincinnati, OH, USA — Sue Barber-Westin

Reference

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Contents

Contributors

Albert T. Anastasio Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Sue Barber-Westin Noyes Knee Institute, Cincinnati, OH, USA

Lefko T. Charalambous Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Niall H. Cochrane Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Timothy Heckmann Noyes Knee Institute, Cincinnati, OH, USA

David L. Kerr Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

A. J. Kievit Department of Orthopedic Surgery, Amsterdam Movement Sciences, Amsterdam Centre for European Studies, Amsterdam University Medical Centers, Amsterdam, Netherlands

P. P. F. M. Kuijer Department of Public and Occupational Health, Amsterdam Public Health Research Institute, Amsterdam Movement Sciences, Amsterdam University Medical Centers, Amsterdam, Netherlands

Frank R. Noyes Cincinnati SportsMedicine and Orthopaedic Center, The Noyes Knee Institute, Cincinnati, OH, USA

M. U. Schafroth Department of Orthopedic Surgery, Amsterdam Movement Sciences, Amsterdam Centre for European Studies, Amsterdam University Medical Centers, Amsterdam, Netherlands

Thorsten M. Seyler Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Mark Wu Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC, USA

Introduction: Epidemiology of Knee Arthroplasty in a Younger Patient Population

1

Sue Barber-Westin and Frank R. Noyes

1.1 Introduction

Total knee arthroplasty (TKA) is one of the most commonly performed elective surgical procedures in the USA, with an exponential growth in volume noted in the past few decades [1–7]. In 2011–2012, an estimated 14–15 million individuals in the USA had symptomatic knee osteoarthritis (OA), of whom more than half had sufficient progression of the disease to warrant consideration for TKA [8]. In 2012, over 700,000 TKAs were performed, for a rate of 223 per 100,000 individuals [9]. This was the highest rate of TKAs among 24 OECD (Organisation for Economic Co-operation and Development) countries studied that year. Other countries with high incidence rates included Austria (218 per 100,000 inhabitants), Germany (206 per 100,000 inhabitants), and Switzerland (205 per 100,000 inhabitants) [10]. Globally, from 2005 to 2011, the highest annual TKA growth rate occurred in patients <65 years of age, and significant associations were noted between increased TKA utilization rates and higher gross national product ($r = 0.53$, $P < 0.01$), greater health expenditures ($r = 0.68$, $P < 0.001$), and obesity ($r = 0.46–0.72$, $P < 0.05$).

Many studies have provided estimated future projections of TKA volume and incidence rates using different epidemiological models [6, 11–15]. Incidence rates are typically calculated as the number of TKAs during a specified time period divided by the size of the US population (using US Census Bureau data) during the same time period. This chapter assesses the most current data available as of May 2020 and discusses factors that affect models and projections for future TKA numbers in the USA. Factors such as age and gender are taken into account when

S. Barber-Westin (✉)
Noyes Knee Institute, Cincinnati, OH, USA
e-mail: sbwestin@csmref.org

F. R. Noyes
Cincinnati SportsMedicine and Orthopaedic Center, The Noyes Knee Institute, Cincinnati, OH, USA

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available. The effect of long-term participation in athletics and sports injuries on the future development of knee osteoarthritis (OA) and potentially TKA is reviewed.

1.2 Historic Annual Numbers and Incidence Rates of Primary TKA in the USA

The number and incidence rates of primary TKA performed in the USA according to various studies are shown in Table 1.1 [3, 6, 7, 9, 12]. Although all of the studies except one [10] used the same databases – the National Inpatient Sample (NIS) taken from the US Healthcare Cost and Utilization Project (HCUP) and the US Census Bureau – the volume and incidence rates varied among the investigations. The NIS is an annual national survey of discharge information from approximately 1000 hospitals and is considered statistically valid because it represents 95% of the US population [12, 15].

In a published report from HCUP, Fingar et al. [9] reported that 421,700 TKAs were performed in 2003, which increased to 700,100 in 2012, representing an overall 66% increase in volume. This study included patients of all ages. Sloan et al. [6] reported fewer procedures (in patients of all ages): 369,405 TKAs in 2012 and 630,509 TKAs in 2013, for an overall 71% increase in volume from 2000. Interestingly, these authors found that the mean annual increase in TKA volume significantly decreased from 2008 to 2014 compared with the time period of 2000–2008 (3.6% and 10.2%, respectively, $P = 0.015$). Inacio et al. [12] reported numbers in patients >40 years of age that were very similar to those of Sloan et al.; however, the incidence rates were more than twice as those of Sloan's for unknown reasons.

Gender comparisons of TKA incidence rates have been conducted in two studies [6, 7], both of which found higher incidence rates in women compared with men (Table 1.2). Williams et al. [7] in a report from the US Department of Health and Human Services found similar increases in the rate of TKA for men and women from 2000 through 2010 (86% and 99%, respectively). However, the rate of TKA for women was higher compared with men in 2000 (33.0 and 24.3 per 10,000, respectively) and in 2010 (65.5 and 45.3 per 10,000, respectively). The difference in rates is most notable in patients aged 45 to 64. Sloan et al. [6] reported large differences in incidence rates between men and women in 2000 and again in 2014. This study also reported large increases in incidence rates according to patient age in 2014 compared with 2000. For instance, the incidence rate in patients aged 65–69 was 498.3 per 100,000 individuals in 2000 and 909.2 per 100,000 individuals in 2014.

As of the time of writing, only two studies estimated prevalence rates of TKA in the USA [16, 17]. Prevalence rates represent the proportion of patients who are alive on a certain date who had TKA, regardless of what year the procedure was performed. One study [16] estimated that in 2010, approximately 4.55% of the entire US population ≥50 years of age, or 4.7 million individuals, had a TKA. The rates increased with each decade of age until ≥90 years and were 1.48% for ages 50–59,

Table 1.1 Historic volume and incidence rates of primary total knee arthroplasty in the USA

Year TKA volume reported	Study	Patient ages studied (year)	Volume TKA	Incidence rate per 100,000 individuals
2000	Sloan et al. [6]	All	274,025	97
	Inacio et al. [12]	≥40	274,463	229
	Kim et al. [3]	All	281,534	Not done
2001	Sloan et al. [6]	All	305,108	107
	Inacio et al. [12]	≥40	305,572	249
	Kim et al. [3]	All	313,618	Not done
2002	Sloan et al. [6]	All	339,225	118
	Inacio et al. [12]	≥40	339,681	272
	Kim et al. [3]	All	350,122	All
2003	Sloan et al. [6]	All	369,405	127
	Inacio et al. [12]	≥40	369,985	290
	Kim et al. [3]	All	379,719	Not done
	Fingar et al. [9]	All	421,700	145.4
2004	Sloan et al. [6]	All	431,852	147
	Inacio et al. [12]	≥40	419,774	323
	Kim et al. [3]	All	431,485	Not done
2005	Sloan et al. [6]	All	482,369	163
	Inacio et al. [12]	≥40	483,067	365
	Kurtz et al. [15]	All	471,088	Not done
	Pabinger et al. [10]	All	Not done	185
2006	Sloan et al. [6]	All	481,941	161
	Inacio et al. [12]	≥40	482,689	358
	Pabinger et al. [10]	All	Not done	175
	Kurtz et al. [13]	All	524,600	Not done
		<45	9900	Not done
		45–54	59,100	Not done
		55–64	147,100	Not done
2007	Sloan et al. [6]	All	532,883	177
	Inacio et al. [12]	≥40	533,602	390
	Pabinger et al. [10]	All	Not done	172
2008	Sloan et al. [6]	All	591,564	194
	Inacio et al. [12]	≥40	592,323	427
	Losina et al. [41]	All	615,050	Not done
	Pabinger et al. [10]	All	Not done	201
2009	Sloan et al. [6]	All	596,939	194
	Inacio et al. [12]	≥40	597,541	424
	Pabinger et al. [10]	All	Not done	213
2010	Sloan et al. [6]	All	632,091	204
	Inacio et al. [12]	≥40	632,862	442
	Williams et al. [7]	≥45	693,400	Not done
	Pabinger et al. [10]	All	Not done	226
2011	Sloan et al. [6]	All	617,945	198
	Inacio et al. [12]	≥40	618,604	426
	Pabinger et al. [10]	All	Not done	235
2012	Sloan et al. [6]	All	630,509	201
	Inacio et al. [12]	≥40	631,214	429
	Fingar et al. [9]	All	700,100	223
2013	Sloan et al. [6]	All	661,695	209
2014	Sloan et al. [6]	All	680,150	213

Table 1.2 Historic annual incidence rates of primary total knee arthroplasty according to gender and age in the USA

Year TKA incidence rate reported	Study	Age (year): incidence rate	Gender: incidence rate	Age (year) and gender: incidence rate
2000	Sloan et al. [6]	<45: 3.0/100,000 45–54: 66.7/100,000 55–64: 249.6/100,000 65–69: 498.3/100,000 70–74: 614.7/100,000 75–79: 635/100,000 80–84: 501.8/100,000 ≥85: 209.9/100,000	Female: 120.7/100,000 Male: 73.1/100,000	Not done
	Williams et al. [7]	Not done	Female: 33.0/10,000 Male: 24.3/10,000	Female 45–64: 16.4/10,000 Male 45–64: 8.7/10,000 Female ≥65: 58.8/10,000 Male >65: 57.0/10,000
2005	Pabinger et al. [10]	≤64: 36/100,000 ≥65: 149/100,000	Not done	Not done
2006	Pabinger et al. [10]	≤64: 35/100,000 ≥65: 140/100,000	Not done	Not done
2007	Pabinger et al. [10]	≤64: 35/100,000 ≥65: 137/100,000	Not done	Not done
2008	Pabinger et al. [10]	≤64: 44/100,000 ≥65: 157/100,000	Not done	Not done
2009	Pabinger et al. [10]	≤64: 48/100,000 ≥65: 165/100,000	Not done	Not done
2010	Pabinger et al. [10]	≤64: 53/100,000 ≥65: 173/100,000	Not done	Not done
2011	Pabinger et al. [10]	≤64: 58/100,000 ≥65: 177/100,000	Not done	Not done
2014	Sloan et al. [6]	<45: 5.8/100,000 45–54: 168.3/100,000 55–64: 525.3/100,000 65–69: 909.2/100,000 70–74: 1016.6/100,000 75–79: 966.6/100,000 80–84: 716.7/100,000 ≥ 85: 259.2/100,000	Female: 259.8/100,000 Male: 165.3/100,000	Not done

Table 1.2 (continued)

Year TKA incidence rate reported	Study	Age (year): incidence rate	Gender: incidence rate	Age (year) and gender: incidence rate
2015	Williams et al. [7]	Not done	Female: 65.5/10,000	Female 45–64: 46.6/10,000
			Male: 45.3/10,000	Male 45–64: 828.6/10,000 Female ≥65: 99.3/10,000 Male >65: 82.6/10,000

4.59% for ages 60–69, 8.80% for ages 70–79, 10.13% for ages 80–89, and 7.40% for ages >90. Women had higher prevalence rates than men for all ages except the ≥90 category (7.39% and 7.41%, respectively). An earlier study [17] published rates that were approximately 20% lower due to differing statistical methods and inclusion of older data. Even so, that study found prevalence rates higher among females than males and increasing rates with each decade of age.

1.3 Projected Volume of TKA

Investigations have used various models, including linear, Poisson, and logistic, to estimate or project future TKA volume and incidence rates [3, 6, 11–15]. Factors entered into the models typically include US Census Bureau data and historic TKA volume calculated from the NIS database, which provides an approximate 20% sample of patients discharged from 1000 hospitals in 44 states, which is 95% representative of the US population [12]. US population growth is projected, and other factors such as age, gender, ethnicity, obesity, and US census region that produce different incidence rates [6, 11, 14, 15] may be included. Poisson and linear regression models assume an exponential or continuous increase in demand for TKA throughout the study time period and have been used most frequently in recent literature [6, 11–14]. A logistic model uses an upper limit (estimated maximum incidence) in the number of TKAs as one of several parameters and produces a more conservative projection [12].

A comparison of projected volume and incidence rates from the most recent studies for the years 2025 to 2050 is shown in Table 1.3. Tremendous variability exists, even in studies that used the same model. For instance, the Poisson model estimates for the total number of TKA for the year 2030 ranged from 1,678,200 to 4,344,900. Two studies conducted analyses according to patient age [6, 13]. The projected volume for patients <45 years of age in 2030 ranged from 9800 to 95,200; for patients aged 45 to 54, from 51,500 to 994,600; and for patients aged 55 to 64, from 162,300 to 1,300,200. These models use historic data to predict data typically at least 10 years ahead, and authors acknowledge there are several limitations in projection methodology. These include the inability to account for future population

Table 1.3 Projected volume and incidence rates of primary total knee arthroplasty in the USA

Year TKA projected	Study/regression model	Age (year)/gender studied	Volume TKA	Incidence rate per 100,000 individuals
2025	Bashinskaya et al. [11]/linear	All	2,428,810	NA
	Inacio et al. [12]/logistic/Poisson	>40	1,027,494/1,446,387	603/849
2030	Bashinskaya et al. [11]/linear	All	3,008,718	NA
	Sloan et al. [6]/linear/Poisson	All	1,252,900/1,678,200	NA
		<45 years	17,900/25,600	NA
		45–54 years	123,500/158,600	NA
		55–64 years	334,800/452,800	NA
		65–69 years	284,400/400,500	NA
		70–74 years	278,200/410,600	NA
		75–79 years	209,400/310,500	NA
		80–84 years	104,600/163,800	NA
		≥85 years	28,600/49,800	NA
		All men	491,100/643,900	NA
		All women	761,800/1,026,100	NA
	Inacio et al. [12]/logistic/Poisson	>40	1,163,697/1,950,967	645/1082
	Kurtz et al. [14]/Poisson	All	3,480,000	NA
	Kurtz et al. [13]/Poisson/constant	All	4,344,900/792,200	NA
		<45 years	95,200/9800	NA
		45–54 years	994,100/51,500	NA
		55–64 years	1,300,200/162,300	NA
2035	Bashinskaya et al. [11]/linear	All	3,394,921	NA
	Inacio et al. [12]/logistic/Poisson	>40	1,286,531/2,621,920	676/1379
2040	Bashinskaya et al. [11]/linear	All	3,656,712	NA
	Inacio et al. [12]/logistic/Poisson	>40	1,383,809/3,479,536	699/1757
2045	Bashinskaya et al. [11]/linear	All	3,884,707	NA
	Inacio et al. [12]/logistic/Poisson	>40	1,463,313/4,587,552	714/2239
2050	Bashinskaya et al. [11]/linear	All	4,174,554	NA
	Inacio et al. [12]/logistic/Poisson	>40	1,531,566/6,030,029	725/2854

numbers, unexpected changes in healthcare systems, politics, surgeon availability, more sports injuries, changes in life expectancy, increasing incidence of obesity, economic resources, recessions, and potential national disasters that limit accessibility to elective surgery (such as the recent COVID-19 pandemic). It is also difficult to project the prevalence of severe symptomatic knee OA, which is increasing rapidly [8, 18]. In addition, these models do not take into account the impact of new technologies – such as cartilage restoration, tissue engineering, and drug therapies – that could lessen the need for TKA. Longer-term projections, such as those 30 years in advance, are expected to be more unreliable [12].

1.4 Impact of Athletic Knee Injuries on Future Osteoarthritis and TKA

Serious knee injuries are a strong risk factor for the development of OA [19–26]. These include anterior cruciate ligament (ACL) ruptures [25, 27, 28], especially those combined with complex meniscus tears requiring meniscectomy [20, 25, 29–31], as well as patellar dislocations [32–34] and complete knee dislocations [35–37]. Recent data suggests that ACL and meniscus injuries significantly increase the risk of a subsequent TKA. In a matched case-control study of 49,723 TKA patients and 104,353 controls in the UK, Khan et al. [38] reported that a history of an ACL injury increased the odds of a subsequent TKA by nearly sevenfold (odds ratio [OR], 6.96; 95% confidence interval [CI] 4.73 to 10.31) and a meniscus injury increased the odds by 15-fold (OR, 15.24; 95% CI 13.88–16.69). The study was based on 20-year longitudinal data, and unfortunately, the investigators were unable to determine the treatment of the ACL and meniscus injuries. However, the findings were similar to those reported by Leroux et al. [39] in a study from Canada that reported that the cumulative incidence of TKA following cruciate ligament reconstruction (ACL or posterior cruciate ligament) was seven times greater than that of a matched control group from the general population (OR, 7.26; 95% CI 5.79–9.11). This study involved 30,277 patients who had undergone cruciate ligament reconstruction and 151,362 individuals from the general population. The majority of patients followed were <50 years of age and had undergone TKA in a mean of 11 years after the knee ligament reconstruction.

A study from Australia found that a history of a sports knee injury more than doubled the odds of a TKA compared with injuries to other areas of the body (OR, 2.41; 95% CI 1.73–3.37), after adjusting for potential confounding factors including age, gender, insurance type, and length of hospital stay for the injury [40]. This study included 64,038 patients who sustained a sports injury between 2000 and 2005 and were followed until 2015. There were 357 patients (0.6%) that required TKA. Suter et al. [21] used the Osteoarthritis Policy Model to project the cumulative incidence of TKA in four patient cohorts: no knee injury, isolated ACL rupture treated conservatively, isolated ACL reconstruction, and ACL reconstruction and medial meniscus tear treated either conservatively or operatively (Table 1.4). Patients who sustained an ACL and meniscus tear by age 25 had a nearly fourfold increase in the estimated lifetime risk of TKA compared with individuals who had no injury (22.3%; 95% CI 16.8–27.9).

Table 1.4 Risk of symptomatic knee osteoarthritis and TKA[a]

Outcome	No injury	Isolated ACL reconstruction[b]	Isolated ACL tear treated conservatively[b]	ACL reconstruction with meniscus tear[b, c]
Lifetime risk of symptomatic knee osteoarthritis	13.5%	16.2%	17.3%	34.2%
Lifetime risk of TKA	6.0%	8.0%	8.9%	22.3%

[a]From Suter et al. [21]
[b]Injured by age 25
[c]Treated in any manner

1.5 Conclusions

In conclusion, the most recent data at the time of writing shows marked increases in the incidence of TKA by 60–70% over the last 15 years. Prior athletic injuries are an important aspect of TKA prevalence. Granted, over the past decade there have been many improved treatment options for common knee ligament injuries and meniscus tears which may be repaired instead of removed that likely will decrease the effect of athletic injuries on knee arthritis in the future. Still, a prior injury (whether athletic or other trauma) increases the odds for subsequent knee replacement surgery in younger and active patients. In addition, there have been major advances in TKA surgery including pre-emptive programs for patient optimization and prehabilitation before surgery, surgical advances of decreasing blood loss and need for transfusion, improved instrumentation for predictable results, and better understanding by patients that the risks of TKA are in fact very small. Patient-reported outcome measures (PROMs) after TKA show major improvements in symptoms and quality of life that have led to more patients requesting the surgery rather than living with advancing knee osteoarthritis. This is a dynamic issue with knee osteoarthritis affecting millions of patients worldwide, and this book is dedicated to showing the major advances that clinics and institutions have implemented that are important to acknowledge and disseminate.

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2 Preoperative Nutrition and General Health Concerns, Patient Indications, and Selection Criteria

Frank R. Noyes and Sue Barber-Westin

2.1 Preoperative Nutrition: Effect of Malnutrition on Total Joint Arthroplasty Outcomes

Malnutrition is a state of altered body composition and function resulting from a lack of nutritional uptake or intake [1] that has been identified from 6% [2] to 26% of total joint arthroplasty patients [3]. Before total knee arthroplasty (TKA), malnutrition is typically defined by serum protein values of albumin (<3.5 g/dL), prealbumin (<16 mg/dL), transferrin (<200 mg/dL), and total lymphocyte count (<1500 cells/mm^3). Albumin is the most widely used marker in orthopedic surgery [4]. It is one of the most abundant proteins that transports fatty acids, steroids, and hormones and is an essential component of serum that plays a crucial role in wound healing and immune function. Patients with low albumin are likely to also lack other important vitamins that are essential for wound healing and proper immune function. They are also more likely to have comorbidities such as liver disease, cardiac disease, and renal malfunction that are associated with higher post-TKA complication rates [5, 6] and hospital charges [7]. Many investigations have reported strong correlations between a low albumin level (<3.5 dg/L) and postoperative total joint arthroplasty complications [5, 6, 8–13].

Prealbumin is a protein synthesized in the liver that is used to formulate other proteins and is also important to assay prior to surgery to determine the nutritional status of the patient. A low level (<16 mg/dL) is indicative of a number of medical conditions including malnutrition, liver disease, digestive disorders, low diet zinc, and hyperthyroidism. Prealbumin reflects short-term changes in nutritional status

F. R. Noyes
Cincinnati SportsMedicine and Orthopaedic Center, The Noyes Knee Institute, Cincinnati, OH, USA

S. Barber-Westin (✉)
Noyes Knee Institute, Cincinnati, OH, USA
e-mail: sbwestin@csmref.org

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and is a more reliable test than serum albumin levels that provides a longer-term assessment. This test has become a standard at joint replacement centers. A serum globulin test may be ordered to assay a patient's overall nutrition and more specifically to diagnose any medical conditions related to the immune system. The normal range for serum globulin is 2.0–3.5 g/dL. Other factors that play a role in immune system function identified in arthroplasty patients include vitamin D, serum zinc, and adiposity [14]. Obesity, low body mass index (BMI), prior gastric bypass, malabsorption states, and hypermetabolic states may also increase the risk of malnutrition.

A systematic review of 20 studies concluded that serologic preoperative malnutrition led to deteriorated postoperative outcomes and increased complications after joint arthroplasty, including increased rates of infection and wound healing problems [10]. Albumin levels were reported in all 20 studies; ninety percent showed a correlation between low albumin content and poorer outcomes, and the authors' meta-analysis indicated that a level <3.5 dg/L had increased odds of developing a postoperative wound complication (odds ratio [OR], 2.18; 95% confidence interval [CI] 1.92–2.47). Roche et al. [13] in a study of 161,625 TKAs reported that patients with low preoperative levels of albumin (<3.5 g/dL), prealbumin (<16 mg/dL), and transferrin (<200 mg/dL) had increased odds of sustaining postoperative complications compared with patients with normal serum protein values (Table 2.1).

Bohl et al. [6] in a study of 49,603 total joint arthroplasty patients reported that compared with patients with normal preoperative albumin concentration, patients with levels <3.5 g/dL had an increased risk for any complication (7.3% vs. 4.0%; relative risk [RR], 1.5; 95% CI 1.2–1.7, $P < 0.001$), for a serious complication (2.1% vs. 1.2%; RR, 1.4; 95% CI 1.0–1.9, $P < 0.05$), for surgical site infection (2.29% vs. 0.96%; RR, 2.0; 95% CI 1.5–2.8, $P < 0.001$), and for pneumonia (1.27% vs 0.30%; RR, 2.5; 95% CI 1.6–4.0, $P < 0.001$). Nelson et al. [12] analyzed 37,143 TKAs and reported multiple statistically significant associations between low albumin and postoperative complications (Table 2.2).

In a study of 1911 total joint arthroplasty patients, Huang et al. [11] reported that malnourished patients (low albumin <3.5 mg/dl or transferrin <200 mg/dl) had a significantly higher risk of any complication compared with normal nourished individuals (12.0% and 2.9%, respectively, $P < 0.001$), as well as a significantly longer

Table 2.1 Odds of sustaining postoperative complications in patients with preoperative malnutrition compared with patients with normal serum protein values (n = 161,625 TKAs)[a]

Preoperative abnormal serum protein value	Infection OR	Wound complication OR	Concomitant infection with wound complication OR	Infection after wound complication OR
Albumin <3.5 g/dL	2.20	2.30	2.90	2.87
Prealbumin <16 mg/dL	1.87	1.90	2.27	2.22
Transferrin <200 mg/dL	1.87	1.90	1.79	1.78

OR odds ratio

[a]From Roche et al. [13]. Note: 95% confidence intervals not provided

Table 2.2 Postoperative complications related to low albumin values <3.5 g/dL (*N* = 37,143 TKAs)[a]

Complication	% Preoperative abnormal albumin	% Preoperative normal albumin	OR, 95% CI	*P* value
Any infection	5.0	2.4	2.0; 1.53–2.61	<0.001
Any major complication	2.4	1.3	1.41; 1.00–1.97	0.05
Blood transfusion	17.8	12.4	1.56; 1.35–1.81	<0.001
Pneumonia	1.21	0.29	3.55; 2.14–5.89	<0.001
Superficial surgical site infection	1.27	0.64	1.27; 1.09–2.75	0.02
Deep surgical site infection	0.38	0.12	3.64; 1.54–8.63	0.003
Unplanned intubation	0.51	0.17	2.24; 1.07–4.69	0.03
Progressive renal insufficiency	0.45	0.12	2.71; 1.21–6.07	0.01
Acute renal failure	0.32	0.06	5.19; 1.96–13.73	0.001
Cardiac arrest requiring resuscitation	0.19	0.12	3.74; 1.50–9.28	0.005
Septic shock	0.38	0.08	4.4; 1.74–11.09	0.002
Mortality	0.64	0.015	3.17; 1.58–6.35	0.001

CI confidence intervals, *OR* odds ratio
[a]From Nelson et al. [12]

length of hospital stay (>3 days, 45% and 16%, respectively, $P < 0.001$). Compared with normal nourished individuals, malnourished patients had significant increases in complications related to cardiovascular (0% and 0.5%, respectively, $P = 0.001$), neurovascular (0% and 2.7%, respectively, $P < 0.001$), renal (0.8% and 5.4%, respectively, $P < 0.001$), irrigation and debridement (0.6% and 2.7%, respectively, $P = 0.002$), hematoma (0.7% and 3.8%, respectively, $P < 0.001$), and infection within 3 months of surgery (0.4% and 2.7%, respectively, $P < 0.001$).

Blevins et al. [5] reported that low albumin was the most specific marker and had the highest positive predictive value compared with other markers (platelets, hemoglobin, and platelet-to-white blood cell ratio) in predicting infection within 2 years of total joint arthroplasty in a study of 30,863 patients. In a multivariate regression model, low albumin increased the odds of development of infection (OR, 4.69; 95% CI 2.43–9.08, $P < 0.0001$). Low hemoglobin (anemia) also significantly increased the odds of infection (OR, 1.73; 95% CI 1.10–2.72, $P = 0.02$). A study of 78 total joint replacements reported that preoperative albumin level was a significant predictor for surgical site infection ($P = 0.01$) [8]. Preoperative and postoperative total lymphocyte count and postoperative albumin were not significant predictors.

Interestingly, the most recent guidelines based on recommendations from the World Health Organization and the Center for Disease Control and Prevention for the prevention of surgical site infection at the time of writing failed to mention preoperative malnutrition issues [15, 16]. A systematic review by Alamanda and Springer [17] on studies that investigated modifiable risk factors for reducing infection recommended albumin or transferrin preoperative testing, as well as advice from a dietitian in the presence of malnutrition. Other methods to detect undernutrition include anthropometric measurements such as calf circumference (<31 cm), arm muscle circumference (<22), and triceps skinfold [4]. However, there are no standard values, and the use of these measurements is not as well supported as the use of serologic laboratory values.

There are also standardized malnutrition screening tools, including the Mini Nutritional Assessment (MNA) that has been shown to be reliable and valid in the geriatric population [18] (Table 2.3). Six questions are answered, and based on the score, 14 other items may then be required to determine nutritional status. Guigoz [18] conducted a review of the sensitivity and specificity of the MNA and concluded this instrument is accurate in identifying nutrition risk. Sensitivity compared with low albumin concentrations ranged from 72% to 100% in eight studies. In addition, receiver operating characteristic curves showed high accuracy of 0.916 for albumin levels <3.5 g/dL.

The subjective global assessment [19] and the Nutritional Risk Screening 2002 (NRS 2002, Table 2.4) [20] are two other commonly used screening tools for malnutrition. Ozkalkanli et al. [21] compared these two instruments in 223 patients scheduled for orthopedic surgery. Sensitivity, specificity, and positive and negative predictive values for the prediction of postoperative complications were calculated. The NRS 2002 had higher sensitivity (69% vs. 50%) and specificity (80% vs. 77%) values and higher OR for the association between malnutrition and occurrence of postoperative complications (4.1 vs. 3.5).

It is important to know all aspects of the dietary status of the patient before surgery including weight loss, change in dietary habits, and loss of appetite. In addition, the psychological status of the patient should be understood including bereavement, loss of a loved one, and home care status. In this regard, the importance of determining the home care that will be provided is paramount. This includes identification of individuals who will provide meals to maintain adequate nutrition, assist with bodily functions, and drive the patient to orthopedic and rehabilitation follow-up visits. The goal is to have the patient remain at home if possible; however, if a postoperative rehabilitation facility is required, the patient's status is closely monitored including diet, hydration, anemia from blood loss, and rehabilitation progress as there may exist quality differences in rehabilitation facilities.

2.2 Effects of Preoperative Obesity and Underweight States

In the USA, the prevalence of obesity (BMI $\geq$ 30 kg/m^2) among adults in 2017–2018 was 42.4%. The rates according to age were 40% in individuals aged 20–39, 44.8% in ages 40–59, and 42.8% in ages ≥60 [22]. Severe obesity (BMI $\geq$ 40 kg/m^2) was present in 9.2% of all adults. In comparison, prevalence rates in 1999–2000 were

Table 2.3 Mini Nutritional Assessment (MNA)[a]

Complete the screening (A–F); if the summed score is <11 points, continue with the remaining questions to derive a malnutrition indicator score		
Question	Responses	Points
A. Has food intake declined over the past 3 months due to loss of appetite, digestive problems, and chewing or swallowing difficulties?	Severe decrease in food intake Moderate decrease in food intake No decrease in food intake	0 1 2
B. Weight loss during the last 3 months	Does not know Between 1 and 3 kg (2.2–6.6 lbs) No weight loss	0 1 2
C. Mobility	Bed or chair bound Able to get out of bed/chair but does not go out Goes out	0 1 2
D. Has suffered psychological stress or acute disease in the past 3 months	Yes No	0 2
E. Neuropsychological problems	Severe dementia or depression Mild dementia No psychological problems	0 1 2
F. Body mass index	<19 19–21 21–23 >23	0 1 2 3
Sum items A–F	*0–7 points: malnourished* *8–11 points: at risk of malnutrition* *12–14 points: normal nutritional status*	
G. Lives independently (not in nursing home or hospital)	No Yes	0 1
H. Takes more than 3 prescription drugs a day	No Yes	1 0
I. Pressure sores or skin ulcers	No Yes	1 0
J. How many full meals does the patient eat daily?	1 meal 2 meals 3 meals	0 1 2
K. Selected consumption markers for protein intake: 1. At least 1 serving of dairy products per day 2. Two or more servings of legumes or eggs per week 3. Meat, fish, or poultry every day	If 0 or 1 yes responses If 2 yes responses If 3 yes responses	0 0.5 1
L. Consumes 2 or more servings of fruit or vegetables per day	No Yes	0 1
M. How much water (water, juice, coffee, tea, milk) is consumed per day	<3 cups 3–5 cups >5 cups	0 0.5 1

(continued)