# Albumin as a Predictor of Total Joint Arthroplasty Complications: A Systematic Review

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## Introduction

The purpose of this paper is to identify whether poor nutrition, as defined by low albumin, will lead to more perioperative complications. If so, then should patients with hypoalbuminemia be considered eligible for elective total joint arthroplasty (TJA) procedures? It is known that there is a risk of perioperative complications after any surgery, including total joint arthroplasty, such as surgical site infection[1,2,19] acute kidney injury (AKI)[14], wound complications[9], pneumonia[2,19], readmission[2,17], unplanned intensive care unit admission[12], and mortality[25]. Albumin is known as a surrogate for nutrition, with the most common lower limit of normal nutrition for normal albumin being 3.5 g/dL[5].

Alternative nutritional markers have been reviewed in the literature with regard to TJA, including total lymphocyte count[16,9] and serum transferrin[8]. However, numerous studies indicate that albumin is associated with risk of perioperative mortality[1,24]. There is variation in selected cutoffs for the lower limit of albumin that leads to perioperative complications with some authors selecting less than 3.0 g/dL[14], less than 3.5 g/dL[2], or less than 3.9 g/dL[24]. Despite variability in albumin cut-point selection, hypoalbuminemia remains an important indicator of malnutrition and its associated perioperative risks[1,14,2]. In this review we hypothesize that hypoalbuminemia as defined by study authors will be associated with increased perioperative complications following TJA. Additionally, we will quantify the extent to which risk is elevated in these patients by combining results from multiple studies.

## Methods

### Literature Search and Study Selection

A systematic review of online databases was conducted in PubMed, EMBASE, and Cochrane Library from November 2017-February 2018. The studies contained keywords relevant to the question, including "albumin", "pre-albumin", "total hip arthroplasty", "total knee arthroplasty", and "total joint arthroplasty". The search term used for all three databases [(((albumin) OR pre-albumin) OR prealbumin) AND ((((((total joint arthroplasty) OR total joint replacement) OR total hip arthroplasty) OR total hip replacement) OR total knee arthroplasty) OR total knee replacement) AND ((((((infection) OR complication) OR readmission) OR readmit) OR postoperative) OR perioperative)] yielded 312 total results in PubMed, 15 total results in EMBASE, and 88 total results in Cochrane Library. These titles were reviewed by independent reviewers (IR): MS and RC. Pertinent English-language articles were considered for inclusion in the final review.

1. 312 PubMed titles, 15 EMBASE titles, and 88 Cochrane Library articles were reviewed for inclusion, and subsequent abstract evaluation.
2. 35 PubMed abstracts, 5 EMBASE abstracts, and 8 Cochrane Library abstracts from the selected titles were reviewed for inclusion, and subsequent full-text evaluation. Abstract review yielded 23 articles from PubMed, 5 articles from EMBASE, and 1 article from Cochrane Library. These 29 articles were selected for full-text review.
3. Of those selected, 28 of 29 articles were able to be obtained for full-text review. Of the 29 original articles included in our search, 3 of the articles were duplicates, with the articles being listed in both PubMed and EMBASE. One additional article, which was not part of the original list of titles, was found during retrieval of full-text articles and was subsequently included in the systematic review. An additional relevant additional article which was published after the start of the systematic review was included.
4. Upon retrieval of 29 of 30 articles, we systematically reviewed the following items: Title, Author, Journal of publication, Year of publication, Primary Outcome, Albumin cutoff used for definition of hypoalbuminemia, Patient Source, Sample Size, Duration of Follow up, Study Design, Complications evaluated, Relative Risk of complication among patients with hypoalbuminemia

### Data Abstraction

Two IR's reviewed all studies and recommended inclusion, based on the title and relevancy to the study question. Next, the IR's recommended inclusion based on the abstract

and relevancy to the study question. Finally, articles were recommended for inclusion based on the full-text article based on relevancy to the study question. Citations from all full-text articles under review were evaluated for additional relevant studies for inclusion. Please see appendix for figures.

### Outcomes of the Papers

After final selection, included studies evaluated numerous perioperative outcomes associated with albumin status. These outcomes included, though are not limited to, postoperative infection, readmission, AKI, mortality, and any cause complication. A meta-analysis was performed using data from all studies that met criteria for inclusion.

## Results

Thirty studies were included for final analysis. Among these, associations between hypoalbuminemia and outcomes of interest were identified in 24 studies. The results showed hypoalbuminemia is significantly associated with higher mortality (OR: 3.17-9.81, 95% CI: 1.46-28.49, p-value: <0.001-0.004), surgical site infection (RR: 2, 95% CI: 1.5-2.8, p-value: <0.011-0.024), pneumonia (RR: 2.5, 95% CI: 1.34-5.89, p-value: <0.001-0.005), revision for septic indication (RR: 3.6, 95% CI: 3.2-4.1, p-value: <0.001), revision for aseptic indication (RR: 2.2, 95% CI: 1.3-3.5, p-value: 0.002), any complication (RR: 1.5, 95% CI: 1.2-1.7, p-value: <0.001), any complication without transfusion (OR: 1.98-2.4, 95% CI: 1.10-3.58, p-value: <0.001-0.023), any major complication (OR: 1.32-2.91, 95% CI: 1.00-7.60, p-value: <0.001-0.05), wound complications (OR: 1.78-2.35, 95% CI: 1.20-3.59, p-value: <0.001-0.005), respiratory complications (OR: 2.35-3.75, 95% CI: 1.27-5.71, p-value: <0.001-0.007), blood transfusions (OR: 1.71-2.34, 95% CI: 1.35-2.83, p-value: <0.001), return to operating room within 30 days (OR: 1.7, 95% CI: 1.15-2.53, p-value: 0.008), extended length of stay (OR: 1.35, 95% CI: 1.14-1.59, p-value: <0.001-0.032), cardiac complications (OR: 2.23, 95% CI: 1.21-4.12, p-value: 0.01), neurovascular complication (OR: 41.95, 95% CI: 3.07-574.07, p-value: 0.005), renal complication (OR: 2.85, 95% CI: 1.2-6.77, p-value: 0.017), hematoma/seroma (OR: 8.37, 95% CI: 1.57-44.66, p-value: 0.013), superficial surgical site infection (OR: 1.27-2.61, 95% CI: 1.09-4.06, p-value: 0.02), deep incisional surgical site infection (OR: 2.3-3.64, 95% CI: 1.12-8.63, p-value: 0.003-0.019), organ space surgical site infection (OR: 2.71-3.79, 95% CI: 1.23-6.21, p-value: <0.001-0.013), unplanned intubation (OR: 2.24-4.11, 95% CI: 1.07-11.74, p-value: 0.008-0.033), acute renal failure (OR: 5.19-7.89, 95% CI: 1.90-32.71, p-value: 0.001-0.004), urinary tract infection (OR: 1.63-3.01, 95% CI: 1.11-5.45, p-value: <0.001-<0.01), sepsis (OR: 5.3, 95% CI: 3.31-8.5, p-value: <0.001), septic shock (OR: 3.73-4.4, 95% CI: 1.11-12.55, p-value: 0.002-0.034), systemic infection (OR: 2.05-3.53, 95% CI: 1.08-4.59, p-value: <0.001-0.028), wound infection (OR: 2.57, 95% CI: 1.79-3.69, p-value: <0.001), cardiac pulmonary complication (OR: 2.49-3.58, 95% CI: 1.01-12.66, p-value: 0.007-0.048), acute kidney injury (OR: 1.82, 95% CI: 1.03-3.24, p-value: 0.041), readmission within thirty days (OR: 0.668 [those with higher albumin levels had a lower chance of being readmitted], 95% CI: 0.477-0.992, p-value: 0.045), unplanned hospital readmission (RR: 1.4, 95% CI: 1.2-1.7, p-value: <0.001), remain on a ventilator for more than 48 hours (OR: 4.03, 95% CI: 1.64-9.90, p-value: 0.002), progressive renal insufficiency (OR: 2.71, 95% CI: 1.21-6.07, p-value: 0.015), cardiac arrest requiring cardiopulmonary resuscitation (OR: 3.74, 95% CI: 1.5-9.28, p-value: 0.005), any infection (OR: 2, 95% CI: 1.53-2.61, p-value: <0.001), acute postoperative infection complicating an aseptic revision arthroplasty (OR: 5.9, 95% CI: 1.317-26.057, p-value: 0.02), chronic septic failure (OR: 2.131, 95% CI: 1.294-3.512, p-value: 0.003).

Meta-analysis was performed among the 9 studies that included sufficient data on patient groups with hypoalbuminemia and normal albumin to perform a combined risk rate (Figure 1).

## Conclusions

Prior studies identified surgical site infection, extended length of stay, acute kidney injury, serous drainage, readmissions, revisions/increased return to operating room, unplanned intensive care unit admission/increased intubations, postoperative complications, major complications, mortality, and a category titled "any complication" that were associated with preoperative hypoalbuminemia. Albumin is a reliable marker for risk of perioperative complications[25,6,7,12,13,2,26,15,19]. With many articles pulling from the ACS-NSQIP[2,3,7,6,19,20,25], and some being done by one surgeon on the team in order to limit variability[26]. Of these, nine studies identified large patient populations undergoing TJA from national databases[2,25,7,13,3,19,6,17,20], sixteen studies were single-surgeon or institution studies[1,18,24,14,8,9,23,4,22,26,15,12,16,21,11,10], and one was a review article and thus did not analyze any patients directly[5]. The purpose of this systematic review is to analyze and merge the results of pertinent studies to provide a summary of the risk for perioperative complications associated with hypoalbuminemia. Based on analysis of the studies, the results show that lower levels of albumin are associated with an odds ratio ranging from 1.27 to 41.95 and relative risks ranging from 2.0 to 3.6 for surgical site infection, pneumonia, revision for septic indications, revision for aseptic indications, postoperative complications, intensive care unit intervention, return to operating room, ninety day readmission, readmission within thirty days, any complication, any complication without transfusion, any major complication, wound complications, respiratory complications, blood transfusions, return to operating room within thirty days, extended length of stay, cardiac complications, mortality, neurovascular complications, renal complications, hematomas/seromas, superficial surgical site infection, deep incisional surgical site infection, organ space surgical site infection, acute postoperative infection complicating an aseptic revision arthroplasty, chronic septic failure/chronic periprosthetic joint infection, any infection, unplanned intubation, acute renal failure, acute kidney injury, progressive renal insufficiency, urinary tract infection, sepsis, septic shock, systemic infection, wound infection, cardiac pulmonary complication, higher resource consumption/
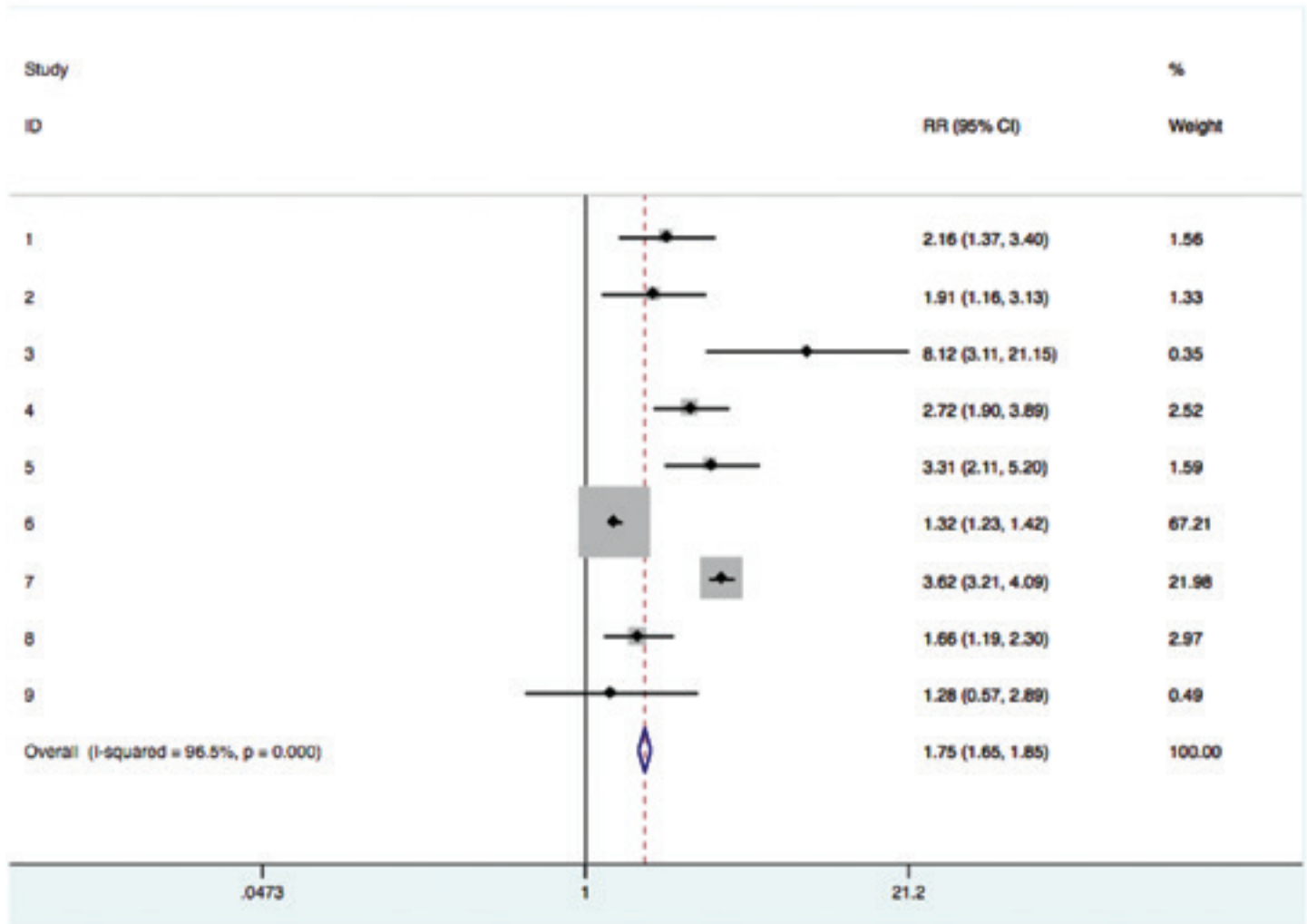
| Study ID | | RR (95% CI) | % Weight |
|---|---|---|---|
| 1 | | 2.16 (1.37, 3.40) | 1.56 |
| 2 | | 1.91 (1.16, 3.13) | 1.33 |
| 3 | | 8.12 (3.11, 21.15) | 0.35 |
| 4 | | 2.72 (1.90, 3.89) | 2.52 |
| 5 | | 3.31 (2.11, 5.20) | 1.59 |
| 6 | | 1.32 (1.23, 1.42) | 67.21 |
| 7 | | 3.62 (3.21, 4.09) | 21.98 |
| 8 | | 1.66 (1.19, 2.30) | 2.97 |
| 9 | | 1.28 (0.57, 2.89) | 0.49 |
| Overall (I-squared = 96.5%, p = 0.000) | | 1.75 (1.65, 1.85) | 100.00 |

Figure 1.

higher charges, higher medical severity of illness, remain on a ventilator for more than forty-eight hours, cardiac arrest requiring cardiopulmonary resuscitation, mortality.

## Discussion and Recommendations

The purpose of this systematic review is to gather all relevant literature on the use of preoperative albumin levels to determine associated risk for perioperative complications. The goals of TJA are to allow patients to improve functional status and reduce pain. Hypoalbuminemia has been previously associated with worsening outcomes after TJA[1,24,25]. Authors have identified numerous types of perioperative complications associated with hypoalbuminemia including mortality, surgical site infection, and renal injury[1,14,9,2,25,7,13,22,19,6,11,10]. However, no prior studies have performed a systematic review or meta-analysis of the data from these many studies to provide a summary risk assessment of hypoalbuminemia.

The main limitation of this project is the heterogeneous complications are incorporated into a single statistic. This limitation is addressed by individual study systematic review.

Our findings show there is an association between hypoalbuminemia and increased perioperative morbidity and mortality. The all-cause combined risk rate was 1.75 (95% CI: 1.65-1.85, p-value: 0.000). Perioperative complications associated with hypoalbuminemia can lead to increased costs, as a result of increased length of stay[6,21,24], increased readmission[17], increased incidence of AKI [Kim], surgical site infection[2], pneumonia[2], urinary tract infection[13,25], cardiopulmonary complications[19], sepsis[13], and death[7,13]. It is important for surgeons to use this information to screen patients[6,7,4] during the perioperative period in order to determine those most at risk for adverse surgical complications. Surgery may be postponed until nutrition is optimized as evaluated by improvement to albumin in the normal range[20], though one study questioned whether postponing surgeries to improve albumin would lead to better perioperative outcomes[4]. This study demonstrates that patients with hypoalbuminemia are associated with increased risk for perioperative complications compared to patients with normal albumin. Patients with normal serum albumin have demonstrated lower rates of reoperation for infection[4], ICU intervention[4], acute renal failure[13], revision total joint arthroplasty for a septic indication[3], early prosthetic joint infection after revision for an aseptic indication[3], fewer postoperative complications[4,6,7], shorter length of stay[15] compared with low serum albumin.

Prospective research into the effect of preoperative albumin optimization is lacking. Future research may focus on the impact of improving albumin and whether this leads to mitigates the risk of perioperative complications imparted by preoperative hypoalbuminemia.

# References

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## Appendix:
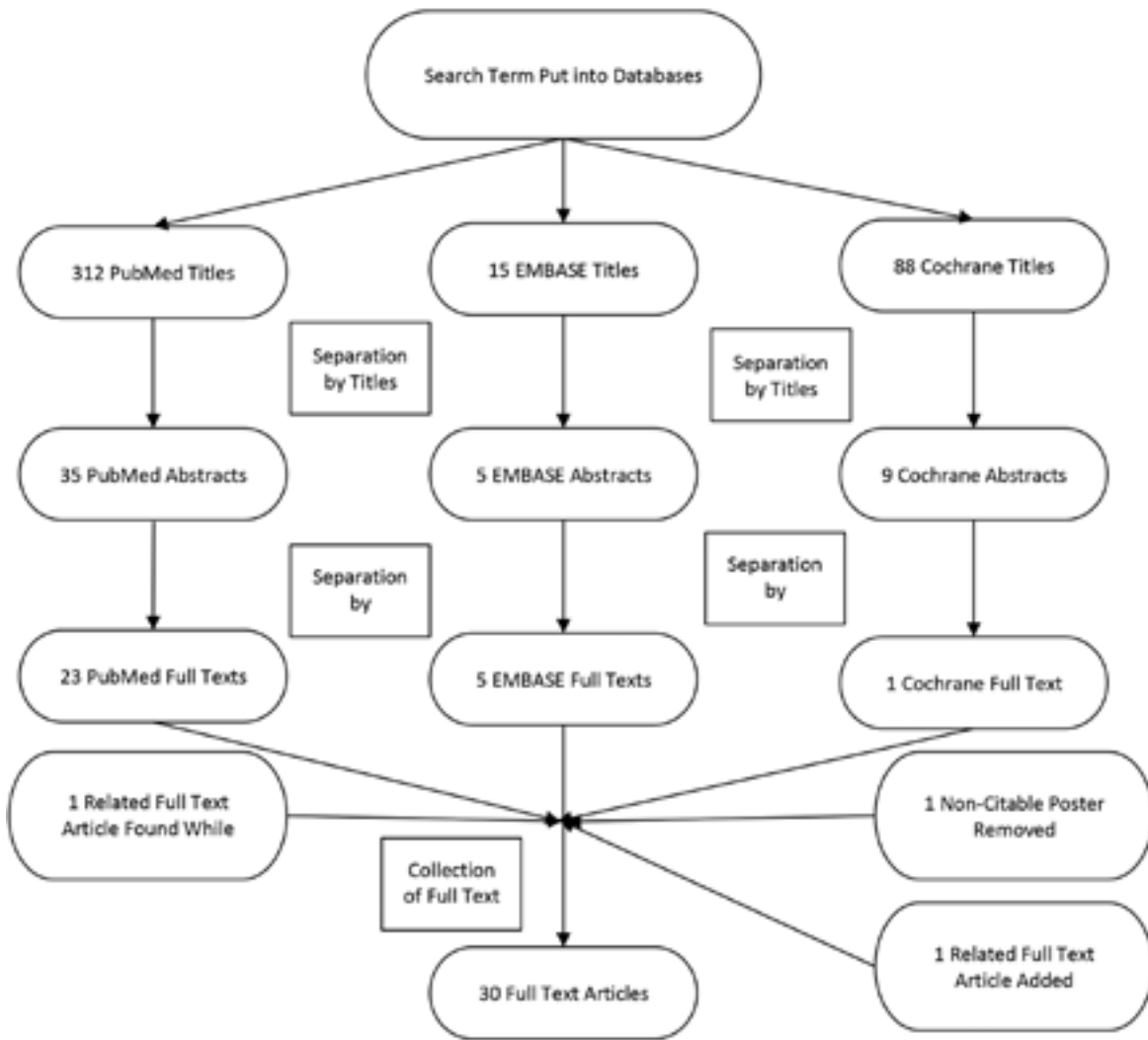


**THA and TKA Studies**

| Author Name | Study Population | Normal Albumin Cutoff |
|---|---|---|
| Alfagierny et al [1] | THA and TKA | Not given |
| Bohl et al [2] | THA and TKA | Albumin <3.5 g/dL is abnormal |
| Bohl et al [3] | THA and TKA | Albumin <3.5 g/dL is abnormal |
| Courtney et al [4] | THA and TKA | Albumin <3.5 g/dL is abnormal |
| Greene et al [5] | THA and TKA | Albumin <3.5 g/dL is abnormal |
| Gunningberg et al [10] | THA, TKA, Coronary Artery Bypass | Albumin <35 g/L is abnormal |
| Huang et al [11] | THA and TKA | Albumin ≤ 3.5mg/dl OR transferrin <200 mg/dl |
| Kamath et al [12] | THA and TKA | Albumin <3.5 g/dL is abnormal |
| Lavernia et al [15] | THA and TKA | Albumin  34 g/L is abnormal |
| Marin et al [16] | THA and TKA | Albumin <3.5 g/dL is abnormal |
| Nussenbaum et al [22] | THA and TKA | Not given |
| Rai et al [23] | THA and TKA | Albumin < 3.5 g/dL or serum transferrin <200 mg/dL or total lymphocyte count <1500 cells/mm$^3$ |

## THA and TKA Studies

| Author Name | Normal Albumin Patient (total) | Low Albumin Patient (total) |
|---|---|---|
| Alfagierny et al [1] | Not given | Not given |
| Bohl et al [2] | 47639 | 1964 |
| Bohl et al [3] | 3762 | 755 |
| Courtney et al [4] | 587 | 83 |
| Greene et al [5] | 211 | 6 |
| Gunningberg et al [10] | 51 | 4 |
| Huang et al [11] | Not given | Not given |
| Kamath et al [12] | 913 | 185 |
| Lavernia et al [15] | 97 | 22 |
| Marin et al [16] | 152 | 18 |
| Nussenbaum et al [22] | Not given | Not given |
| Rai et al [23] | Not given | Not given |

## THA and TKA Studies

| Author Name | Study Type | Control Group |
|---|---|---|
| Alfagierny et al [1] | Retrospective Cohort | N/A |
| Bohl et al [2] | Retrospective Cohort | N/A |
| Bohl et al [3] | Retrospective Cohort | N/A |
| Courtney et al [4] | Retrospective Cohort | N/A |
| Greene et al [5] | Retrospective Cohort | N/A |
| Gunningberg et al [10] | Prospective Cohort | N/A |
| Huang et al [11] | Prospective Cohort | N/A |
| Kamath et al [12] | Prospective Cohort | N/A |
| Lavernia et al [15] | Prospective Cohort | N/A |
| Marin et al [16] | Prospective Cohort | N/A |
| Nussenbaum et al [22] | Retrospective Cohort | 520 THA and TKA |
| Rai et al [23] | Retrospective Cohort | N/A |

## THA and TKA Studies

| Author Name | Experimental THA | Experimental TKA |
|---|---|---|
| Alfagierny et al [1] | 25 | 110 |
| Bohl et al [2] | 29628 | 19975 |
| Bohl et al [3] | 2199 | 2318 |
| Courtney et al [4] | 236 | 434 |
| Greene et al [5] | 126 | 91 |
| Gunningberg et al [10] | 32 | 23 |
| Huang et al [11] | 910 | 1001 |
| Kamath et al [12] | Not given | Not given |
| Lavernia et al [15] | Not given | Not given |
| Marin et al [16] | 92 | 78 |
| Nussenbaum et al [22] | 475 THA and TKA | 475 THA and TKA |
| Rai et al [23] | 33 | 7 |

## THA and TKA Studies

| Author Name | Outcomes |
| --- | --- |
| Alfagierny et al [1] | Surgical Site Infection |
| Bohl et al [2] | Multiple Complications |
| Bohl et al [3] | Aseptic and Septic Indications for Revision Arthroplasty |
| Courtney et al [4] | Multiple Postoperative Complications |
| Greene et al [5] | Persistent Serous Drainage, Wound Dehiscence |
| Gunningberg et al [10] | Surgical Wound Infection |
| Huang et al [11] | Multiple Complications |
| Kamath et al [12] | Unplanned Postoperative Intensive Care Unit Admission |
| Lavernia et al [15] | Multiple Complications, Length of Stay |
| Marin et al [16] | Delayed Wound Healing |
| Nussenbaum et al [22] | Multiple Complications, Death |
| Rai et al [23] | Wound Healing |

## THA and TKA Studies

| Author Name | Conclusions |
| --- | --- |
| Alfagierny et al [1] | Perioperative albumin is a significant risk factor for surgical site infection. |
| Bohl et al [2] | Patients with hypoalbuminemia had higher risk of surgical site infection, pneumonia, extended length of stay, and readmission. |
| Bohl et al [3] | Patients with hypoalbuminemia were more likely to have septic and aseptic indications for revision arthroplasty compared to patients with normal albumin levels. |
| Courtney et al [4] | Hypoalbuminemic patients are more likely to have postoperative complications. Morbidly obese patients are more likely to be hypoalbuminemic that nonmorbidly obese patients. When stratifying albumin with obesity, the difference lied in albumin levels. |
| Greene et al [5] | A low total lymphocyte count has increased risk of a major wound complication, and a low albumin level of an even higher risk. |
| Gunningberg et al [10] | Low preoperative S-albumin was identified as the only significant predictor for surgical wound infection. |
| Huang et al [11] | Malnutritioned patients have higher risk of complications than in non-malnutritioned patients, regardless of obesity. Renal complications were the most common complication experienced by malnourished patients. |
| Kamath et al [12] | Patients with low albumin have a higher risk of unplanned postoperative intensive care unit admission. |
| Lavernia et al [15] | Patients with low albumin levels have higher charges, higher severity of illness, and longer length of stay. |
| Marin et al [16] | Low preoperative lymphocyte count is associated with increased risk of healing complications, whereas preoperative serum albumin and transferrin levels had no significant predictive value. |
| Nussenbaum et al [22] | Implementation preoperative screening criteria for THA and TKA decreased complications. No single criterion was found to individually predict the complication and infection reductions. |
| Rai et al [23] | Controlling surgeon-dependent factors allows decreases in wound healing complications related to malnourishment. |

## THA and TKA Studies

| Author Name | Year | Mean Follow-Up Time |
|---|---|---|
| Alfagierny et al [1] | 2015 | 6 months |
| Bohl et al [2] | 2016 | 30 days |
| Bohl et al [3] | 2016 | 30 days |
| Courtney et al [4] | 2016 | 6 months |
| Greene et al [5] | 1991 | 1 year |
| Gunningberg et al [10] | 2008 | 30 days |
| Huang et al [11] | 2013 | 12 months |
| Kamath et al [12] | 2016 | Not given |
| Lavernia et al [15] | 1999 | Not given |
| Marin et al [16] | 2002 | Not given |
| Nussenbaum et al [22] | 2018 | 2 years |
| Rai et al [23] | 2002 | Not given |

## THA Studies

| Author Name | Study Population | Normal Albumin Cutoff |
|---|---|---|
| Fu et al [6] | THA | Albumin < 3.5g/dL is abnormal |
| Gherini et al [8] | THA | Not given |
| Mednick et al [17] | THA | Not given |
| Nelson et al [20] | THA | Albumin < 3.5 g/dL is abnormal |
| Nicholson et al [21] | THA | Albumin < 3.5 g/dL is abnormal and TLC < 1.50 cells/m |
| Savio et al [24] | THA | Albumin < 3.5 g/dL is abnormal, then they changed it to albumin < 3.9 g/dL is normal after analyzing their data |
| Walls et al [25] | THA | Albumin < 3.5 g/dL is abnormal |

## THA Studies

| Author Name | Normal Albumin Patient (total) | Low Albumin Patient (total) |
|---|---|---|
| Fu et al [6] | 19465 | 745 |
| Gherini et al [8] | Not given | Not given |
| Mednick et al [17] | Not given | Not given |
| Nelson et al [20] | 23409 | 1177 |
| Nicholson et al [21] | 64 | 26 |
| Savio et al [24] | 51 | 35 |
| Walls et al [25] | 23116 | 1122 |

## THA Studies

| Author Name | Study Type | Control Group |
|---|---|---|
| Fu et al [6] | Retrospective Cohort | N/A |
| Gherini et al [8] | Prospective Cohort | N/A |
| Mednick et al [17] | Retrospective Cohort | N/A |
| Nelson et al [20] | Retrospective Cohort | 23409 THA |
| Nicholson et al [21] | Retrospective Cohort | N/A |
| Savio et al [24] | Retrospective Cohort | N/A |
| Walls et al [25] | Retrospective Cohort | N/A |

## THA Studies

| Author Name | Experimental THA | Experimental TKA |
|---|---|---|
| Fu et al [6] | 20210 | 0 |
| Gherini et al [8] | 103 | 0 |
| Mednick et al [17] | 9441 | 0 |
| Nelson et al [20] | 1177 | 0 |
| Nicholson et al [21] | 90 | 0 |
| Savio et al [24] | 86 | 0 |
| Walls et al [25] | 49475 | 0 |

## THA Studies

| Author Name | Outcomes |
|---|---|
| Fu et al [6] | Postoperative Complications: Cardiac (Myocardial Infarction or Cardiac Arrest), Septic (Sepsis or Septic Shock), Respiratory (Intubation, Ventilator Requirement, Superficial Infection, or Organ Space Infection), Urinary (Urinary Tract Infection), Blood Transfusions, Deep Vein Thrombosis or Pulmonary Embolism, Return to the Operating Room within 30 Postoperative Days, Extended Length of Stay (defined as 4 or more days), and Death. A Major Postoperative Complication was defines as any cardiac, respiratory, or septic complication, in addition to deep vein thrombosis and/or pulmonary embolism, return to operating room, or death. |
| Gherini et al [8] | Delayed Wound Healing |
| Mednick et al [17] | Readmission |
| Nelson et al [20] | Any Complication, Any Complication without Transfusion, Cardiac Pulmonary Complications, Major Complications, Systemic Infection, Wound Infection |
| Nicholson et al [21] | Length of Stay, Intraoperative Complications: Femoral Fractures, Blood Loss Treated by Transfusion, Death, Postoperative Complications: Early Revisions of the Prosthesis Within the First Month, Deep Prosthetic or Superficial Wound Infection, Dislocation, Myocardial Infarctions, Pulmonary Embolism, Acute Renal Failure, Deep Vein Thrombosis, Urinary Tract Infection, Pressure Sore, Paralytic Ileus, Peri-prosthetic Fracture following a Fall, Recurrent Dislocation, Early Subsidence of the Graft, Haematoma, Wound Infections, Death |
| Savio et al [24] | Length of Stay |
| Walls et al [25] | Complications: Mortality, Superficial Incisional Surgical Site Infection, Deep Incisional Surgical Site Infection, Organ Space Surgical Site Infection, Surgical Wound Disruption, Pneumonia, Unplanned Intubation, Pulmonary Embolism, on Ventilator > 48 Hours, Progressive Renal Insufficiency, Acute Renal Failure, Urinary Tract Infection, Stroke/CVA, Coma > 24 Hours, Peripheral Nerve Injury, Cardiac Arrest Requiring CPR, Sepsis, and Septic Shock |

## THA Studies

| Author Name | Conclusions |
| --- | --- |
| Fu et al [6] | Malnutrition incidence increased significantly from obese I to obese III patients and was a stronger and more consistent predictor than obesity of complications after THA. |
| Gherini et al [8] | Only preoperative serum transferrin levels showed significant value in predicting which patients would have delayed wound healing. None of the other serologic variables, including serum albumin and total lymphocyte count, proved to be a predictor of delayed wound healing. |
| Mednick et al [17] | The risk of readmission following total hip arthroplasty increases with growing preoperative comorbidity burden, and it is specifically increased in patients with a body mass index of greater than or equal to 40 kilograms per meter squared, a history of corticosteroid use, and low preoperative serum albumin and in patients with postoperative surgical site infection, a thromboembolic event, and sepsis. |
| Nelson et al [20] | Three out of six of the measurable complications for patients with albumin < 3.0 g/dL showed statistical significance for increased odds ratio for complications, and when stratified for patients with albumin < 2..75 g/dL, five out of six of the measurable complications showed statistical significance for an increase in odds ratio. |
| Nicholson et al [21] | The rate of malnourishment was significantly higher in patients having trauma-related surgery than in those having elective surgery. Malnourished patients are at greater risk of prolonged hospital stay. |
| Savio et al [24] | Preoperative serum albumin was the only preoperative serum test associated with length of stay. Albumin is inversely related with length of stay. There should be a new normal range for albumin, because prolonged recovery time may be identified preoperatively be using a serum albumin level of less than 3.9 g/dL. Because specific complications occurred in so few patients, a larger sample is required to show any association with preoperative malnutrition. |
| Walls et al [25] | Hypoalbuminemia is a significant risk factor for mortality and major morbidity among total hip arthroplasty patients, while morbid obesity was only associated with an increased risk of superficial surgical site infection. |

## THA Studies

| Author Name | Year | Mean Follow-Up Time |
| --- | --- | --- |
| Fu et al [6] | 2016 | 30 days |
| Gherini et al [8] | Not given | Not given |
| Mednick et al [17] | 2014 | 30 days |
| Nelson et al [20] | 2018 | 30 days |
| Nicholson et al [21] | 2012 | Not given |
| Savio et al [24] | 1996 | 1.8 years |
| Walls et al [25] | 2015 | 30 days |

## TKA Studies

| Author Name | Study Population | Normal Albumin Cutoff |
| --- | --- | --- |
| Fu et al [7] | TKA | Albumin 3.5 g/dL is abnormal |
| Kim et al [14] | TKA | Albumin ≥ 3.0 g/dL is normal |
| Morey et al [18] | TKA | Albumin < 3.5 g/dL is abnormal |
| Nelson et al [19] | TKA | Albumin < 3.5 g/dL is abnormal |

### TKA Studies

| Author Name | Normal Albumin Patient (total) | Low Albumin Patient (total) |
|---|---|---|
| Fu et al [7] | 33400 | 1400 |
| Kim et al [14] | 839 | 470 |
| Morey et al [18] | 2956 | 213 |
| Nelson et al [19] | 35573 | 1570 |

### TKA Studies

| Author Name | Study Type | Control Group |
|---|---|---|
| Fu et al [7] | Retrospective Cohort | N/A |
| Kim et al [14] | Retrospective Cohort | N/A |
| Morey et al [18] | Retrospective Cohort | N/A |
| Nelson et al [19] | Retrospective Cohort | N/A |

### TKA Studies

| Author Name | Experimental THA | Experimental TKA |
|---|---|---|
| Fu et al [7] | 0 | 34800 |
| Kim et al [14] | 0 | 1309 |
| Morey et al [18] | 0 | 3169 |
| Nelson et al [19] | 0 | 77785 |

### TKA Studies

| Author Name | Outcomes |
|---|---|
| Fu et al [7] | Postoperative Complications: Wound (Superficial Infection, Deep Surgical Site Infection, Organ Space Surgical Site Infection, or Wound Dehiscence), Septic (Sepsis or Septic Shock), Cardiac (Cardiac Arrest or Myocardial Infarction), Respiratory (Pneumonia, Intubation, or Ventilator Requirement), Blood Transfusions (Intra- or Postoperative), Urinary Tract Infection, Return to the Operating Room within 30 days, Deep Vein Thrombosis or Pulmonary Embolism, Extended Length of Stay (defined as 4 days or longer), and Death. Major complications were defined as any septic, cardiac, or respiratory complications, as well as DVT, PE, or return to OR, and death. |
| Kim et al [14] | Incidence of Acute Kidney Injury, Hospital Stay, and Overall Mortality |
| Morey et al [18] | Wound Complications (Drainage, Hemarthrosis, Skin Necrosis, Dehiscence), or Periprosthetic Joint Infection |
| Nelson et al [19] | Mortality, Superficial Wound Infection, Deep Incisional Wound Infection, Organ Space Surgical Site Infection, Surgical Wound Disruption, Pneumonia, Unplanned Intubation, Pulmonary Embolism, on Ventilator More than 48 Hours, Progressive Renal Insufficiency, Acute Renal Failure, Urinary Tract Infection, Stroke/Cerebrovascular Accident, Coma More than 24 Hours, Peripheral Nerve Injury, Cardiac Arrest Requiring Cardiopulmonary Resuscitation, Myocardial Infarction, Blood Transfusion, Prosthesis Failure, Deep Vein Thrombosis, Sepsis, and Septic Shock |

### TKA Studies

| Author Name | Conclusions |
| --- | --- |
| Fu et al [7] | Hypoalbuminemia is a more consistent independent predictor of complications after TKA than obesity. |
| Kim et al [14] | Low albumin within 2 postoperative days is an independent risk factor for acute kidney injury and increased length of hospital stay in patients undergoing TKA. |
| Morey et al [18] | Our findings call into question the values of serum albumin level and TLC as a surrogate of malnutrition for predicting wound complications after TKA. |
| Nelson et al [19] | Morbid obesity is not independently associated with the majority of perioperative complications measured by the NSQIP and was associated only with increases in progressive renal insufficiency, superficial surgical site infection, and sepsis among the 21 perioperative variables measured. Low serum albumin was associated with increased mortality and multiple additional major perioperative complications after TKA. Low serum albumin, more so than morbid obesity, is associated with major perioperative complications. |

### TKA Studies

| Author Name | Year | Mean Follow-Up Time |
| --- | --- | --- |
| Fu et al [7] | 2017 | 30 days |
| Kim et al [14] | 2016 | 4.2 years |
| Morey et al [18] | 2016 | 1 year |
| Nelson et al [19] | 2015 | 30 days |

### Revision THA Studies

| Author Name | Study Population | Normal Albumin Cutoff |
| --- | --- | --- |
| Yi et al (26) | Revision THA | Albumin < 3.5 g/dL is abnormal |

### Revision THA Studies

| Author Name | Normal Albumin Patient (total) | Low Albumin Patient (total) |
| --- | --- | --- |
| Yi et al (26) | Not given | Not given |

### Revision THA Studies

| Author Name | Study Type | Control Group |
| --- | --- | --- |
| Yi et al (26) | Retrospective Cohort | N/A |

### Revision THA Studies

| Author Name | Experimental THA | Experimental TKA |
| --- | --- | --- |
| Yi et al (26) | 501 | 0 |

### Revision THA Studies

| Author Name | Outcomes |
| --- | --- |
| Yi et al (26) | Septic Revision, Aseptic Revision |

### Revision THA Studies

| Author Name | Conclusions |
| --- | --- |
| Yi et al (26) | The presence of one or more laboratory parameters suggestive of malnutrition (low albumin, low transferrin, low lymphocyte count), though common in both normal weight and overweight patients, is independently associated with both chronic PJI and the development of an acute postoperative infection after an aseptic revision arthroplasty. |

| Revision THA Studies | | |
|---|---|---|
| **Author Name** | **Year** | **Mean Follow-Up Time** |
| Yi et al (26) | 2014 | 90 days |

| Revision TKA Studies | | |
|---|---|---|
| **Author Name** | **Study Population** | **Normal Albumin Cutoff** |
| Kamath et al [13] | Revision TKA | Albumin < 3.5 g/dL is abnormal |

| Revision TKA Studies | | |
|---|---|---|
| **Author Name** | **Normal Albumin Patient (total)** | **Low Albumin Patient (total)** |
| Kamath et al [13] | 3838 | 713 |

| Revision TKA Studies | | |
|---|---|---|
| **Author Name** | **Study Type** | **Control Group** |
| Kamath et al [13] | Retrospective Cohort | N/A |

| Revision TKA Studies | | |
|---|---|---|
| **Author Name** | **Experimental THA** | **Experimental TKA** |
| Kamath et al [13] | 0 | 4551 |

| Revision TKA Studies | |
|---|---|
| **Author Name** | **Outcomes** |
| Kamath et al [13] | Mortality, Superficial Wound Infection, Deep Incisional Wound Infection, Organ Space Surgical Site Infection, Surgical Wound Disruption, Pneumonia, Unplanned Intubation, Pulmonary Embolism, on Ventilator More than 48 Hours, Progressive Renal Insufficiency, Acute Renal Failure, Urinary Tract Infection, Stroke/Cerebrovascular Accident, Coma More than 24 Hours, Peripheral Nerve Injury, Cardiac Arrest Requiring Cardiopulmonary Resuscitation, Myocardial Infarction, Bleeding Transfusion, Prosthesis Failure, Deep Vein Thrombosis, Sepsis, and Septic Shock |

| Revision TKA Studies | |
|---|---|
| **Author Name** | **Conclusions** |
| Kamath et al [13] | Patients in the low serum albumin group were statistically more likely to develop deep surgical site infection, organ space surgical site infection, pneumonia, urinary tract infection, sepsis, unplanned intubation, blood transfusion intraoperatively or postoperatively, remain on a ventilator for more than 48 hours, develop acute renal failure, coma, and mortality. |

| Revision TKA Studies | | |
|---|---|---|
| **Author Name** | **Year** | **Mean Follow-Up Time** |
| Kamath et al [13] | 2017 | 30 days |

| Review Paper | | |
|---|---|---|
| **Author Name** | **Study Population** | **Normal Albumin Cutoff** |
| Cross et al [5] | N/A | N/A |

| Review Paper | | |
|---|---|---|
| **Author Name** | **Normal Albumin Patient (total)** | **Low Albumin Patient (total)** |
| Cross et al [5] | N/A | N/A |

| Review Paper | | |
|---|---|---|
| **Author Name** | **Study Type** | **Control Group** |
| Cross et al [5] | N/A | N/A |

| Review Paper | | |
| --- | --- | --- |
| **Author Name** | **Experimental THA** | **Experimental TKA** |
| Cross et al [5] | N/A | N/A |

| Review Paper | | |
| --- | --- | --- |
| **Author Name** | **Outcomes** | **Conclusions** |
| Cross et al [5] | N/A | N/A |

| Review Paper | | |
| --- | --- | --- |
| **Author Name** | **Year** | **Mean Follow-Up** |
| Cross et al [5] | 2014 | N/A |