REVIEW ARTICLE

Enhanced Recovery after Total Joint Arthroplasty (TJA): A Contemporary Systematic Review of Clinical Outcomes and Usage of Key Elements

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Background: Enhanced recovery after surgery (ERAS) is a pathway designed to improve the care of surgical patients and achieve early recovery. The clinical outcomes and usage of key elements of ERAS pathways in total joint arthroplasty (TJA) need further reanalysis. This article aims to provide an overview of the latest clinical outcomes and current usage of key elements of ERAS pathways in TJA.

Methods: We undertook a systematic review of the PubMed, OVID, and EMBASE databases in February 2022. Studies investigating the clinical outcomes and usage of key elements of ERAS in TJA were included. The components of successful ERAS programs and their usage were further determined and discussed.

Results: Twenty-four studies involving 216,708 patients assessed ERAS pathways for TJA. A total of 95.8% (23/24) of studies reported a reduced length of stay (LOS), followed by reduce overall opioid consumption or pain (87.5% [7/8]), save costs (85.7% [6/7]), improvements in patient-reported outcomes or functional recovery (60% [6/10]), and reduced incidence of complications (50% [5/10]). In addition, preoperative patient education (79.2% [19/24]), anesthetic protocol (54.2% [13/24]), use of local anesthetics for infiltration analgesia or nerve blocks (79.2% [19/24]), perioperative oral analgesia (66.7% [16/24]), perioperative surgical factors including reduced use of tourniquets and drains (41.7% [10/24]), use of tranexamic acid (41.7% [10/24]) and early mobilization (100% [24/24]) were contemporary comparatively "active" components of ERAS.

Conclusions: ERAS for TJA has favorable clinical outcomes in terms of reducing LOS and overall pain, saving costs, accelerating functional recovery, and reducing complications, although the evidence is still low in quality. In the current clinical scenario, only some "active" components of the ERAS program are widely used.

Key words: Enhanced Recovery After Surgery; Perioperative Care; Postoperative Care; Systematic Review; Total Joint Arthroplasty

Introduction

Total joint arthroplasty (TJA) is one of the most commonly performed elective surgical procedures in the world, and its volume has risen in recent decades.[1] The rapid increase in TJA volume along with huge medical costs poses a great challenge to our healthcare system, of which excess length of hospital stay (LOS) accounts for most of the total costs.[2] Enhanced recovery after surgery (ERAS) pathways are multidisciplinary care pathways that integrate multiple evidence-based interventions to improve perioperative management, hasten recovery, and improve clinical outcomes as well as save costs.[3] Studies have shown that ERAS adoption optimizes patient care and experience during the perioperative pathway, resulting in reduced LOS and risk of complications with significant hospital cost savings.[4,5]

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Several components have been proposed for the ERAS pathway, including preoperative information education and counseling, preoperative optimization, and preoperative fasting. These protocols are being improved constantly. A recent consensus recommended by the ERAS® Society proposed 17 key recommendations for perioperative care in total hip replacement and total knee replacement surgery.[6] The consensus does provide guidance for perioperative care for TJA patients; however, the recommended key elements may not be widely accepted in clinical practice. In addition, due to the complexity of executing completely recommended ERAS protocols, studies are still needed to simplify the protocols or determine the most important components of care. To achieve the above goals, the contemporary use of the key elements of ERAS pathways in TJA as well as its clinical outcomes should be reviewed.

Regarding the clinical outcomes of the ERAS pathway, most of the studies have reported confusing overall results. Some studies have reported that ERAS usage results in a reduced LOS and a decreased incidence of complications for hip and knee arthroplasty.[7,8] Others found that the ERAS pathway reduced LOS after primary TJA but had minimal to no impact on perioperative complications.[9] In addition, the performance and importance of individual components in TJA remain controversial, and the available evidence in the literature has not been systematically reviewed until now.[10] Therefore, the aims of this study are (1) to reanalyze the contemporary performance and clinical outcomes of ERAS in TJA and (2) to evaluate the current usage of ERAS components in TJA and determine the "active" components.

Methods

Search Strategy and Study Selection

The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. For the principal literature search, we searched the PubMed, OVID, and EMBASE databases to identify relevant articles published prior to February 2022. Medical subject heading terms as well as accompanying entry terms were used. The search parameters were "enhanced postsurgical recovery", "enhanced postoperative recovery", "enhanced recovery after surgery", "enhanced recovery", "accelerated recovery", "fast track recovery", "fast track surgery", "recovery program" or "recovery pathway," and "total hip arthroplasty" or "total knee arthroplasty."

Exclusion and Inclusion Criteria

The criteria of ERAS pathways were defined as follows: (1) included a bundle of multiple perioperative interventions, (2) had labeled differences from traditional care or controlled pathways, and (3) had a formal way of measuring outcomes. Outcome measures included LOS, incidence of complications, readmission rates, patient-reported outcomes or functional recovery, overall opioid consumption or pain, costs, and/or patients' anxiety and depression or patient satisfaction.

For the full-text screening, two reviewers independently screened each article based on the following inclusion criteria: (1) the intervention met our study's definition of an ERAS pathway and (2) the article specifically addressed clinical outcomes of ERAS pathway implementation and described the usage of the elements of the ERAS pathway. As the protocols of the ERAS pathway are constantly being improved, it is important to identify studies that have been more recent in the past 5 years. Therefore, we included original studies if they met the above inclusion criteria from any randomized controlled trials (RCTs), retrospective, or prospective studies within the past 5 years.

We excluded studies published before 2017, studies concerning unicompartmental knee replacement, studies without extractable data, studies without addressed clinical outcomes, comments, case reports, posters or letters, editorials, conference abstracts, irrelevant or narrative reviews, guidelines, study protocols, and non-English studies. Disagreements about study selection were resolved through discussion.

Data Extraction and Quality Assessment

The data of eligible studies were extracted after study selection. The following characteristics were extracted from each study: first author, year of publication, number of patients, study design, mean age, controlled pathway, ERAS program, findings, and outcomes. For statistical description, categorical variables are presented as frequencies and percentages, while continuous variables are presented as the means.

RCTs[11] were appraised using the Jadad score, which ranges from 0 to 5, with 5 being optimal. Nonrandomized studies (prospective or retrospective) were appraised using the Methodological Index for Nonrandomized Studies (MINORS) criteria, which range from 0 to 16, with a higher score reflecting higher quality.[12] Disagreements about study quality were resolved by discussion with a review author until consensus was reached. All studies were appraised by two authors.

Results

Study Selection and Demographic Characteristics

Our original search identified 2761 publications on total joint arthroplasty. After excluding duplicates, we screened 2291 titles and abstracts; 2229 papers were excluded based on their titles and abstracts. We therefore reviewed the full texts of 62 articles. We excluded 38 studies after reviewing the full texts (the reasons for exclusion are given in Figure 1). Finally, 24 studies (n = 216,708) published after 2017 were included; these studies compared the traditional care or controlled pathway (n = 209,330) to ERAS (n = 7378) strategies (Table 1). Of these studies, 14 studies[13–26] retrospectively compared the ERAS pathway with historical or standard controls, and eight[27–34] prospectively described ERAS pathways with associated controls. The remaining two[35,36] studies were conducted as RCTs. Details are shown in Table 1.

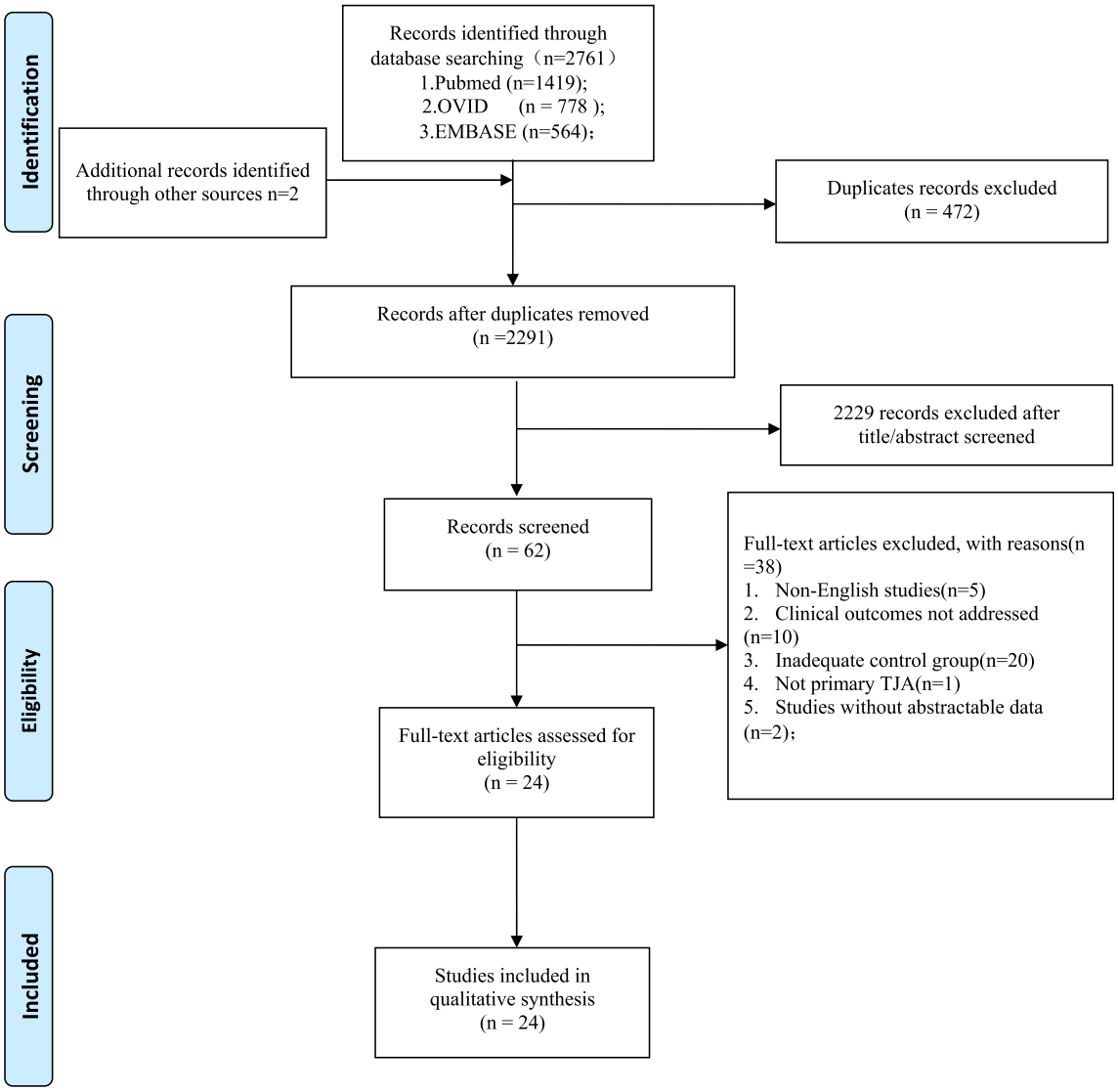

FIGURE 1 Selection process according to the preferred reporting items for systematic reviews and meta-analyses statement

Quality Assessment

The quality of the included studies was variable, with an average MI-NORS score of 9.5 points (range 8–12) and average Jadad scores of 2.5 points (range 2–3), which demonstrates a relatively low study quality. Considerable heterogeneity between individual pathways limits comparisons. Thus, we conducted a systematic review due to the generally poor quality of the studies. The MI-NORS and Jadad scores of each study are shown in Table 1.

Latest Clinical Outcomes

LOS

The results of LOS varied considerably (Table 2). Among them, 95.8% (23/24) of the studies reported a significantly reduced LOS of the ERAS pathway to different degrees compared with the standard/traditional pathway, but one study reported a reduced LOS without statistical significance.

Complications

The results of complications were also varied, and nine studies reported outcomes (Table 2). A total of 55.6% (5/9) of the studies found that the ERAS pathway had a reduced incidence of complications compared with the traditional pathway. Ripollés-Melchor et al.[27] found that patients with the highest adherence to ERAS components had fewer overall postoperative complications. Jiang et al.[29] reported that the ERAS pathway had significantly fewer total complications without a significant difference in short-term mortality. Venditoli et al.[30] found that the ERAS pathway had a significantly lower rate of grade 1 and 2 complications according to the Clavien–Dindo classification; however, the difference

TABLE 1 Study characteristics and patient demographics

Authors	Study Design	Included number of patients(ERAS pathway)	Surgery	Female (n, %)	Age (Range)	Level of evidence	Quality assessment
Javier Ripollés-Melchor 2020[27]	Prospective cohort study	6146 (1592)	THA/TKA	3580 (58.2%)	interquartilerange 71 (63–76, IQR)	III	12 (MI-NORS)
Sergio Castorina 2018[13]	Retrospective observational study	132 (95)	TKA	NA	72.1	IV	11 (MI-NORS)
Angela Elizabeth Marchisio 2020[35]	Randomized double blinded clinical trial	48 (23)	THA	22 (45.8%)	64.46 ± 10.37	II	3 (Jadad)
Joris A Jansen 2020[14]	Retrospective cohort	686 (403)	TKA	206 (30%)	68 years (range 46–88)	III	10 (MI-NORS)
Robert H Thiele 2021[15]	Retrospective cohort	1681 (833)	THA/TKA	426 (53.1%)	64.5 (55–72)	III	11 (MI-NORS)
Nicole Lay Tin Tan 2018[28]	Prospective cohort study	230 (121)	THA	153 (66.5%)	64.05	III	12 (MI-NORS)
Hong-Hui Jiang 2019[29]	Prospective controlled study	247 (106)	TKA	141 (49.8%)	74.9	III	12 (MI-NORS)
M M T Chung 2021[16]	Retrospective cohort	228 (111)	THA/TKA	145 (63.6%)	50–89	III	9 (MI-NORS)
Anouk G M Didden 2019[17]	Retrospective cohort	170 (85)	TKA	194 (71.9%)	69	III	9 (MI-NORS)
Pascal-André Vendittoli 2019[30]	Prospective cohort	264 (114)	THA/TKA	137 (51.9%)	55.9	III	11 (MI-NORS)
Aymard De Ladoucette 2020[31]	Prospective observational study	105,864 (1110)	THA	611 (55%)	67.5 ± 11.9	III	10 (MI-NORS)
Jean-Yves Jenny 2021[32]	Observational prospective study	97,168 (839)	TKA	525 (62.6%)	70.3 ± 9.3	III	10 (MI-NORS)
Chiara Arienti 2020[33]	Prospective, case–control study	43 (20)	TKA	33 (76.7%)	69 (50–82)	III	11 (MI-NORS)
Bas L Fransen 2018[36]	Non-blinded RCT	49 (25)	TKA	20 (40.8%)	62.5	II	2 (Jadad)
Raul Frankllim de Carvalho Almeida 2021[18]	Retrospective cohort	98 (47)	THA	48 (49%)	N/A	III	10 (MI-NORS)
David J Milligan 2021[19]	Retrospective cohort	200 (100)	THA/TKA	126 (63%)	65.75	III	9 (MI-NORS)
Meiyan Zhong 2021[34]	Prospective cohort study	348 (180)	THA	197 (56.6%)	64.5	III	11 (MI-NORS)
Baptiste Picart 2021[20]	Retrospective case-control study	551 (216)	TKA	N/A	69.06 ± 9.29 (37–92)	III	10 (MI-NORS)
Daniel Plessl 2020[21]	Retrospective observational study	323 (194)	TKA	217 (67.2%)	67.1	III	9 (MI-NORS)
Yehoshua Gleicher 2021[22]	Retrospective observational study	615 (383)	TKA	376 (61.1%)	66.3	III	9 (MI-NORS)
Georgios I Drosos 2020[23]	Retrospective study	114 (67)	THA/TKA	89 (78.1%)	70.4	III	9 (MI-NORS)
Blake J Schultz 2019[24]	Retrospective study	216 (108)	THA/TKA	N/A	63.15	III	9 (MI-NORS)
David P Gwynne-Jones 2017[25]	Retrospective study	1035 (528)	THA/TKA	N/A	68.6	III	8 (MI-NORS)
John M Yanik 2018[26]	Retrospective cohort	252 (78)	THA/TKA	25 (9.9%)	66.1	III	9 (MI-NORS)

TABLE 2 Summary of clinical outcomes after Implementation of ERAS programs

	Reduced LOS	Reduced incidence of complications	Reduced readmission rates	Improvements in patient-reported outcomes or functional recovery	Reduce overall opioid consumption or pain	Save costs	Decreased anxiety and depression or improved patient satisfaction	Others
Javier Ripollés-Melchor 2020[27]	√	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	
Sergio Castorina 2018[13]	√	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	
Angela Elizabeth Marchisio 2020[35]	√	Not mentioned	Not mentioned	No difference	Not mentioned	Not mentioned	Not mentioned	Higher muscle strength
Joris A Jansen 2020[14]	√	No difference	Not mentioned	No difference	Not mentioned	√	Not mentioned	
Robert H Thiele 2021[15]	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Aggregate increase in profit
Nicole Lay Tin Tan 2018[28]	√(Not statistically significant)	Not mentioned	8 in ERAS and 5 in traditional pathway	No difference	No difference	Not mentioned	Not mentioned	
Hong-Hui Jiang 2019[29]	√	√	Not mentioned	√(Short term)	Not mentioned	No difference	Not mentioned	Decreased intraoperative blood loss, total blood loss, transfusion rate
M M T Chung 2021[16]	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	
Anouk G M Didden 2019[17]	√	Not mentioned	√	Improved functional recovery time	Not mentioned	Not mentioned	Not mentioned	
Pascal-André Vendittoli 2019[30]	√	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	
Aymard De Ladoucette 2020[31]	√	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	
Jean-Yves Jenny 2021[32]	√	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	
Chiara Arienti 2020[33]	√	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	
Bas L Fransen 2018[36]	√	No difference	Not mentioned	√(First week)	√(First 7 days)	Not mentioned	Not mentioned	
Raul Franklim de Carvalho Almeida 2021[18]	√	No difference	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Decreased blood transfusion and usage of the critical care unit
David J Milligan 2021[19]	√	Not mentioned	No difference	Not mentioned	Not mentioned	√	Not mentioned	ERAS patients had a small increases in postoperative resource usage
Meiyan Zhong 2021[34]	√	√	Not mentioned	Not mentioned	√	Not mentioned	√	

TABLE 2 Continued

	Reduced LOS	Reduced incidence of complications	Reduced readmission rates	Improvements in patient-reported outcomes or functional recovery	Reduce overall opioid consumption or pain	Save costs	Decreased anxiety and depression or improved patient satisfaction	Others
Baptiste Picart 2021[20]	√	Not mentioned	No difference	Not mentioned	√	Not mentioned	Not mentioned	
Daniel Plessl 2020[21]	√	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	
Yehoshua Gleicher 2021[22]	√	Not mentioned	√	Not mentioned	√	Not mentioned	Not mentioned	
Georgios I Drosos 2020[23]	√	No difference	No difference	Not mentioned	Not mentioned	Not mentioned	Not mentioned	
Blake J Schultz 2019[24]	√	√	No difference	Not mentioned	Not mentioned	√	Not mentioned	
David P Gwynne-Jones 2017[25]	√	Not mentioned	No difference	√	Not mentioned	Not mentioned	√	30-day readmission rate increased from 3.2% to 5.5% ($p = 0.065$)
John M Yanik 2018[26]	√	No difference	No difference	Not mentioned	Not mentioned	√	Not mentioned	Lower unplanned readmissions and overall complications without statistically significance
Total	95.8% (23/24)	50% 5/10)	36.4% (4/11)	60% (6/10)	87.5% (7/8)	85.7% (6/7)	2	

TABLE 3 Summary of current usage of the key elements recommended by EARS society

	Preoperative information, education, and counseling	Preoperative optimization	Preoperative fasting	Standard anesthetic protocol	Perioperative surgical factors	Use of local anesthetics for infiltration analgesia(1) and nerve blocks(2)	Maintaining normothermia	Perioperative fluid management	Postoperative nausea and vomiting	Prevention of perioperative blood loss	Perioperative oral analgesia	Antimicrobial prophylaxis	Antithrombotic prophylaxis treatment	Postoperative nutritional care	Early mobilization	Criteria-based discharge	Continuous improvement and audit	Others
Javier Ripollés-Melchor 2020[27]	√	√	√	Not mentioned	Not mentioned	√(1)	√	√	√	Not mentioned	Not mentioned	√	√	√	√	Not mentioned	Not mentioned	Postoperative glycemic control
Sergio Castorina 2018[13]	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Parapatellar medial incision; no tourniquet fascia and articular drainage; continuous elastomeric pumps infusion for pain control
Angela Elizabeth Marchisio 2020[35]	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Spinal anesthesia; posterior approach
Joris A Jansen 2020[14]	√	Not mentioned	Not mentioned	√	√	√(1)	Not mentioned	Not mentioned	√	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Spinal anesthesia; No wound drains, urinary catheters or patient-controlled analgesia pumps
Robert H Thiele 2021[15]	√	Not mentioned	√	Not mentioned	Not mentioned	√(1 + 2)	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	
Nicole Lay Tin Tan 2018[28]	√	Not mentioned	√	√	Not mentioned	Not mentioned	√	√	√	√	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Increase in spinal anesthesia and decrease in general anesthesia
Hong-Hui Jiang 2019[29]	√	√	√	√	Not mentioned	√(1)	√	√	√	√	√	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	Spinal (preferred) or general anesthetic; Joint function and Lung function exercise
M M T Chung 2021[16]	√	Not mentioned	Not mentioned	√	√	√(1 + 2)	Not mentioned	Not mentioned	√	√	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Spinal anesthesia(preferred); medial parapatellar approach; higher dose of intravenous steroid; hypnotics
Anouk G M Didden 2019[17]	√	Not mentioned	Not mentioned	√	Not mentioned	√(1)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	spinal analgesia or general anesthesia
Pascal-André Vendittoli 2019[30]	√	√	√	√	√	√(1)	Not mentioned	√	Not mentioned	√	√	√	√	√	√	Not mentioned	Not mentioned	Spinal (preferred) or general anesthetic; no tourniquet
Aymard De Ladoucette 2020[31]	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√(1)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	√	Not mentioned	√	√	Not mentioned	
Jean-Yves Jenny 2021[32]	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√(1 + 2)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	One dose of peri-operative glucocorticoids
Chiara Arienti 2020[33]	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	√(1)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Sub-vastus approach *vs*. midline approach
Bas L Fransen 2018[36]	√	Not mentioned	Not mentioned	Not mentioned	√	√(1)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	No tourniquet; sub-vastus approach *vs*. midline approach; no pain pumps, wound drains or bladder catheters

Raul Franklim de Carvalho Almeida 2021[18]	√	Not mentioned	Not mentioned	√	√	√(1)	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Spinal or general Anesthetic; no delayed bladder catheterization
David J Milligan 2021[19]	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	√	Post- discharge phone call one day after discharge
Meiyan Zhong 2021[34]	√	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Nutrition assessment before and after the operation
Baptiste Picart 2021[20]	√	√	√	Not mentioned	√	√(1)	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	√	√	√	Not mentioned	No perineural block, tourniquet or drainage. An intra-articular catheter was fitted for less than 24 h
Daniel Plessl 2020[21]	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	√(2)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Planned discharge to home on the day of surgery; spinal anesthesia with a single adductor block
Yehoshua Gleicher 2021[22]	√	Not mentioned	Not mentioned	√	√	√(1 + 2)	Not mentioned	Not mentioned	√	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	No preoperative catheterization and intermittent catheterization; shorter duration spinal anesthetics
Georgios I Drosos 2020[23]	√	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√(1)	Not mentioned	Not mentioned	Not mentioned	√	√	√	√	Not mentioned	√	Not mentioned	√	
Blake J Schultz 2019[24]	√	√	Not mentioned	√	Not mentioned	√(1)	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Perioperative spinal anesthesia; Peripheral nerve blocks were not routinely used
David P Gwynne-Jones 2017[25]	√	√	Not mentioned	√	Not mentioned	√(1 + 2)	√	√	Not mentioned	√	√	Not mentioned	Not mentioned	Not mentioned	√	√	Not mentioned	Day of surgery admission; Spinal anesthesia + intrathecal morphine
John M Yanik 2018[26]	√	Not mentioned	Not mentioned	√	Not mentioned	√(1)	Not mentioned	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Not mentioned	√	Not mentioned	Not mentioned	Implementation of spinal anesthesia and elimination of femoral nerve blocks
Total	79.2% (19/24)	16.7% (4/24)	29.2% (7/24)	54.2% (13/24)	41.7% (10/24)	79.2% (19/24)	20.8% (5/24)	29.2%(7/24)	29.2%(7/24)	41.7% (10/24)	66.7% (16/24)	12.5%(3/24)	16.7% (4/24)	16.7% (4/24)	100% (24/24)	33.3%(8/24)	8.3%(2/24)	

in complications of grades 3, 4, or 5 was not significant. Schultz et al.[24] also found that the ERAS protocol had significantly fewer overall complications than traditional protocols (7% vs. 21%), specifically fewer acute medical complications (4% vs. 12%). Zhong et al.[34] reported that the ERAS pathway had lower incidences of deep vein thrombosis in the lower limbs, urinary tract infection, and pulmonary infection than the standard pathway. However, the rest of the studies found no notable difference in the overall postoperative complication rate between ERAS and the standard/traditional pathway (Table 3).

Readmission Data

Eleven studies reported appropriate readmission data, and three were prospective studies. A total of 36.4% (4/11) of studies found that the ERAS pathway decreased readmission rates. However, Tan et al.[28] reported mildly increased readmission rates. They found that eight of 115 patients had an unplanned readmission in the ERAS pathway for reasons including hip fractures, urinary retention, and allergies. Five of 115 patients in the traditional/standard pathway had an unplanned readmission to the hospital for reasons including hip fractures, surgical infection, pneumonia and pain management.

Functional Outcome

Ten studies reported functional outcomes, of which three were prospective studies and two were RCTs. Sixty percent (6/10) of studies found that the ERAS pathway improved patient-reported outcomes or functional recovery. Fransen et al.[36] found that patients in the ERAS pathway had significantly lower knee pain scores and improved functional outcomes in the first 7 days after TKA compared to a regular protocol. Similarly, Jiang et al.[29] also found that ERAS patients had higher KSS scores of the knee than traditional patients at POD 1 and POD 5; they also found that ERAS patients had a significantly increased ROM degree at POD 1; however, the ROM of the knee tended to be comparable at POD 5.

Pain Management

Eight studies assessed the impact of the ERAS pathway on pain management in patients undergoing TJA. A total of 87.5% (7/8) of patients in the ERAS pathway had reduced pain parameters. Fransen et al.[36] found that ERAS patients have lower mean VAS scores for knee pain than their controls during movement with weight bearing of the affected knee in the first 7 days, which is significant on POD4 and POD6, and the pain tended to decrease during the following time up to 12 weeks and remained at comparatively lower levels than that in the standard/traditional patients.

Hospitalization Cost and Patients' Experience

Seven studies reported the effect of the ERAS pathway on hospitalization costs. A total of 85.7% (6/7) of studies favored the usage of the EARS pathway in TJA to achieve cost-effectiveness. However, few studies have reported changes in anxiety, depression, or satisfaction in patients after undergoing ERAS. Only two studies[25,34] found that ERAS implementation decreased anxiety and depression or improved patient satisfaction compared with the traditional/standard pathway.

Current Usage of the Key Elements

The guidelines recommended by the ERAS Society[6] described and proposed 17 key ERAS components for total hip replacement and total knee replacement surgery. As seen from our results, the usage of the ERAS pathway has been widely accepted in TJA to achieve an accelerated recovery of patients. However, the components of the ERAS pathway were used differently, although there are some coordinated "active" components.

Preadmission Phases

Preoperative Education

Preoperative education can provide information about perioperative exercise, rehabilitation, and expectations of LOS, which is useful to reduce the anxiety of patients but improve their understanding of the surgery. A total of 79.2% (19/24) of studies recorded the usage or partial usage of preoperative information, education, and expectation counseling. The largest study was conducted by Ripolles-Melchor et al.[27] which was a prospective cohort study that included 1592 patients who adopted the ERAS pathway. They conducted preoperative education on the ERAS pathway via verbal and written consent; however, the details of education were not mentioned.

Preoperative Phases

Preoperative Optimization

The aim of optimization is to optimize preoperative risk factors, such as smoking, alcohol consumption, anemia, nutritional and metabolic status, and low physical activity, to reduce the occurrence of potential complications or a prolonged length of stay. However, only 16.7% (4/24) of studies highlighted the usage of preoperative optimization in their ERAS protocols.

Preoperative Fasting

The traditional purpose of fasting is to reduce the risk of aspiration at the induction of anesthesia.

The ERAS society recommended the intake of clear fluids until 2 h before the induction of anesthesia and a 6-h fast for solid food.[6] However, only 29.2% (7/24) of studies highlighted this strategy as a part of their EARS protocols.

Perioperative Oral Analgesia

Pain can heavily limit the recovery of patients, while appropriate analgesia can facilitate early postoperative mobility and recovery. Perioperative oral analgesia in the ERAS

pathways may yield additional pain relief for patients undergoing TJA, especially using nonopioid oral analgesia, including paracetamol and NSAIDs. A total of 66.7% (16/24) of studies highlighted the usage of perioperative oral analgesia in their EARS pathway.

During Surgery Phases

Anesthetic Protocol: Systemic and Regional Anesthesia

A consensus of the standard anesthetic protocol in the ERAS setting is still lacking. A total of 54.2% (13/24) of studies highlighted the importance of the anesthetic protocol in their ERAS pathway. Among them, 84.6% (11/13) chose a spinal-preferred anesthetic protocol. Only two studies[17,18] reported that both spinal analgesia and general anesthesia were acceptable. However, Palanne et al.[37] found through a randomized controlled trial that for TKA patients, spinal anesthesia shared a similar condition with general anesthesia in terms of 24-h postoperative opioid consumption, pain management, blood transfusions, in-hospital complications, and length of hospital stay; however, vomiting incidence in the spinal anesthesia group was higher than that in the general anesthesia group.

Regional or local anesthesia plays a vital role in controlling postoperative pain and enhancing mobilization. Among them, local infiltration analgesia (LIA) has an advantage over nerve blocks because it produces no motor blockade and has little interference effect on muscle strength. In addition, 79.2% (19/24) of studies reported the use of local anesthetics for nerve blocks or infiltration analgesia as an important part of their EARS protocols. In addition, 63.2% (12/19) of studies adopted the intraoperative use of local infiltration analgesia. A prospective study compared LIA, peripheral nerve blocks, general and spinal anesthesia on early functional recovery, and pain control in primary TKA, and they found that pain relief was comparable within the four groups and that LIA showed significant advantages in mobilization and muscle strength in the early postoperative period.[38]

Prevention of Perioperative Blood Loss

Pronounced blood loss was indicated in TJA, and tranexamic acid (TXA) has been favored to decrease blood loss and reduce the risk for transfusion.[39] Studies have demonstrated that the use of TXA is both efficient and safe and has little effect on the risks of venous thromboembolic events[39]; even 3 g of TXA has no significant effect on the level of D-dimer, an important diagnostic parameter of thrombosis.[40,41] Furthermore, a systematic review and meta-analysis also revealed that TXA plus drain clamping is more efficient than its control (including TXA alone and drain clamping alone) to control blood loss after TKA, which can significantly reduce the need for transfusion, total blood loss, blood loss in drainage, and the decrease in hemoglobin.[42] In this review, we found that only 41.7% (10/24) of the studies reported the use of TXA to prevent perioperative blood loss.

Maintaining Normothermia

Failing to maintain perioperative normothermia can result in devastating physiologic consequences, including increased catabolism and wound infections as well as increased surgical bleeding.[43] Therefore, maintaining normothermia in TJA patients should be targeted as an important part of anesthetic care. However, only 20.8% (5/24) of the studies highlighted this strategy in their ERAS protocols.

Antimicrobial Prophylaxis

Infection after TJA is a serious consequence that is difficult to treat, and evidence has demonstrated that TJA patients benefit from surgical antibiotic prophylaxis.[44] Antimicrobial prophylaxis is now the standard of care for patients receiving hip or knee arthroplasty.[45] A systematic review and meta-analysis conducted by Siddiqi et al.[44] found that surgical antibiotic prophylaxis continued beyond 24 h in TJA and added no benefit to the prevention of surgical site infection. However, for patients at high risk for infection, extended postoperative antibiotic prophylaxis may lead to a statistically significant reduction in the 90-day infection rate after primary TJA.[46] However, only 12.5% (3/24) of the studies highlighted antimicrobial prophylaxis in their EARS pathways.

Perioperative Surgical Factors

Perioperative surgical factors may influence outcomes, complications, and recovery rates. Among them, the use of a tourniquet may aggravate muscle injury and cause swelling, increase postoperative pain, and impair early functional recovery, while drainage may increase blood loss and the transfusion rate.[47,48] A total of 41.7% (10/24) of the studies highlighted the importance of perioperative surgical factors in their ERAS protocols. Sixty percent (6/10) of studies[13,14,16,33,35,36] reported the use of specific surgical approaches; 50% (4/8) of studies[13,20,30,36] with knee replacement highlighted the reduced or abandoned use of tourniquets; and 60% (6/10) of studies[13,14,18,20,22,36] did not support the routine use of drains. Furthermore, only two studies[13,36] supported the use of specific surgical approaches and reduced or abandoned the use of tourniquets and drains. Though surgical approach is hotly discussed in TJA, the preferred surgical approach was not highlighted or recommended in the guidelines as well as recent publications[6,10]; of which, subvastus approach for TKA was reported to have increased ROM at 6 months post-surgery and short-term recovery favors limited incision over standard incision for THA.[49,50] Thus, the surgical approach that could support ERAS still remains controversial.

Perioperative Fluid Management

Maintaining fluid balance should be regarded as an important part of ERAS pathways because either too little or too much fluid in the perioperative period may be associated with an increased risk of complications and prolongation of hospital stay.[51] Surgical stress may result in renal

vasoconstriction and salt and water retention.[52] Therefore, balanced crystalloids should be preferred to avoid salt overload.[51] Optimized fluid management in the ERAS pathway, such as a minimized period of preoperative fasting, limited intraoperative blood and fluid loss, and the early intake of postoperative oral fluids, should be judiciously used. Within ERAS, both restricted and balanced fluid management protocols as well as goal-directed therapy (GDT) have been advocated.[6] In this review, only 29.2% (7/24) of the studies highlighted perioperative fluid management protocols in their ERAS pathways.

After Surgery Phases

Antithrombotic Prophylaxis Treatment

Thromboembolism is a major preventable cause of mortality, morbidity, and delayed discharge, and its methods of prophylaxis include mechanical (such as graduated compression stockings and intermittent calf compression) and pharmacological (such as low-molecular-weight heparins) methods.[53] Only 16.7% (4/24) of studies highlighted antithrombotic prophylaxis in their EARS pathways.

Postoperative Nausea and Vomiting

Postoperative nausea and vomiting (PONV) remain common and distressing complications following surgery, which can negatively affect nutritional postoperative recovery, prolong the hospital stay, and increase medical costs.[54] Key PONV risk factors include female sex, increasing duration of surgical procedures, and intraoperative and postoperative opioids.[55] PONV can be reduced or minimized by prophylactically administering antiemetic agents such as ondansetron.[56] In addition, dexamethasone is also safe and efficacious for the prophylaxis of PONV, which can decrease the incidence and severity of PONV and is associated with less frequent administration of antiemetic agents.[57] Only 29.2% (7/24) of studies highlighted PONV prophylaxis in their ERAS protocols.

Postoperative Early Feeding

Return to normal food intake as soon as possible following surgery is recommended. The benefits of early postoperative feeding include decreased postoperative ileus, improved wound healing, reduced wound complications, and a faster recovery.[58,59] A randomized controlled trial demonstrated that early postoperative feeding can safely begin approximately 4 hr after elective THA, which showed no difference in nausea, return of bowel function, or LOS compared with late postoperative feeding (⩾8 h postoperatively).[60] Only 16.7% (4/24) of studies highlighted early postoperative feeding in their EARS protocols.

Early Mobilization

Early mobilization may hasten functional recovery after surgery, which has been shown to reduce LOS approximately 1.8 days after TJA.[61] Early mobilization has been widely adopted to facilitate early discharge in the last 5 year. of ERAS protocols. A total of 100% (24/24) of studies encouraged patients to mobilize as early as possible.

Criteria-Based Discharge and Continuous Improvement and Audit

A total of 33.3% (8/24) of studies defined the requirements of discharge for EARS patients; however, only 8.3% (2/24) of studies supported continuous improvement and auditing as an element of their ERAS protocols. Milligan et al.[19] introduced a postdischarge phone call 1 day after discharge and patient access to a 24/7 dedicated helpline to reduce LOS, while Drosos et al.[23] chose to encourage patients to have regular follow-ups in the outpatient clinic from where they were discharged to their homes.

Discussion

After the introduction of the ERAS concept, an increasing number of studies have been conducted and have demonstrated the superiority of the ERAS pathway over traditional/standard treatment. ERAS programs have been demonstrated to be safe, efficacious, acceptable, and widely applicable in the perioperative period and share a number of similarities across a range of specialties. Our review is an attempt to appraise the overall results of contemporary ERAS pathways and the current usage of the recommended components by the ERAS® Society in TJA. We showed that ERAS for TJA has favorable clinical outcomes in terms of reducing LOS and overall pain, saving costs, accelerating functional recovery, and reducing complications, although the evidence is still low in quality. In addition, the content of currently used ERAS protocols is varied and significantly heterogeneous. These dramatic variations in clinical programs demonstrate the lack of consensus in practice. However, the ERAS pathway in contemporary studies had some coordinative "active" components.

In this systematic review, we sought to review the direct evidence for each recommended component of ERAS within TJA that has been demonstrated to be clearly effective. However, due to the great variation in ERAS programs, direct evidence for individual components of EARS is still lacking. Nevertheless, we still identified some "active" components of ERAS in TJA. These components include preoperative patient education, anesthetic protocol, use of local anesthetics for infiltration analgesia or nerve blocks, perioperative oral analgesia, perioperative surgical factors including reduced use of tourniquets and drains, use of tranexamic acid, and early mobilization. We believe these "active" components of recommendations are clinically effective key components in TJA, which may be the strongest contributing factors of the recommendations of the ERAS® Society. However, further studies are still needed to verify our hypothesis.

There is no denying that the pros of enhanced recovery after total joint arthroplasty are evident; however, the cons should not be neglected. The results in this review showed that reduced readmission rates, decreased anxiety and

depression, and improved patient satisfaction were less reported outcomes in the current ERAS project. This may in turn indicate that the consensus of these outcomes was not widely reached. For example, some patients may feel unready or reluctant to be discharged to their home for safety concerns, although they are physically capable.[62] In addition, some aged patients may have problems in the perception of discharge teaching.[63] These reasons may have a negative influence on readmission, anxiety and depression, or patient satisfaction. Therefore, a whole course of auditing the rehabilitation process after TJA is necessary. Various measures of promoting the quality of discharge teaching or providing postdischarge support, such as postdischarge phone calls and guidance, to achieve successful rehabilitation of TJA should be advocated.

Our study has a number of limitations. First, although a comprehensive literature search was conducted, we may omit some relevant non-English studies or studies not referenced in the included databases. Second, low-quality assessment of the included studies indicated a high risk of bias. Third, the heterogeneity of ERAS protocols may heavily influence the validity of this systematic review. Although challenges exist, the implementation of full ERAS protocols does have many benefits. Thus, studies with higher quality data, such as high-quality RCTs, are needed to determine the effect of fully recommended ERAS protocols or the effect of "active" components of recommendations to provide optimal recommendations for clinical practice.

Conclusion

ERAS for TJA has favorable clinical outcomes in terms of reducing LOS and overall pain, saving costs, accelerating functional recovery, and reducing complications, although the evidence is still low in quality. In the current clinical scenario, only some "active" components of the ERAS program are widely used.

Authors' Contributions

CJ C participated in the drafting, writing, and revising of the manuscript. L JK, Y Y, W YG, R YJ and Z DB participated in the data selection and analysis. PD K participated in the conception and design of the study and contributed to analysis and interpretation of the data and they approved the final version of the manuscript to be submitted, and agreed to be accountable for all aspects of the work.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Availability of Data and Material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for Publication

The authors have seen and approved the manuscript.

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