Does an ERAS-based perioperative protocol improve functional outcomes and length of stay after primary total hip arthroplasty in patients over 65?

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Medical Studies
DOI: https://doi.org/10.5114/ms/230859

Key words: functional outcome, elderly patients, hip osteoarthritis, enhanced recovery after surgery, primary hip arthroplasty.

Abstract

Introduction: Total hip arthroplasty is the treatment of choice for advanced hip osteoarthritis, particularly in older adults with pain and marked functional limitation. Enhanced Recovery After Surgery (ERAS) protocols have been introduced to optimise perioperative care and improve postoperative recovery.
Aim of the research: To evaluate whether the authors' perioperative protocol based on ERAS principles improves outcomes compared with standard care in patients over 65 years of age undergoing primary total hip arthroplasty.
Material and methods: A total of 362 patients qualified for primary hip arthroplasty were included. The standard treatment group (ST) comprised 121 patients, whereas the authors' protocol group (AU) included 241 patients. Outcomes were assessed using the Harris Hip Score (HHS), WOMAC, Physical Activity Scale for the Elderly (PASE), Numeric Rating Scale (NRS), length of hospital stay, and the number of intra- and postoperative complications. Measurements were performed preoperatively and 12 months postoperatively, except for complications, which were assessed up to 30 days after surgery.
Results and conclusions: Both groups showed significant postoperative improvement in HHS, WOMAC, PASE, and NRS scores. However, significantly better functional outcomes were observed in the AU group, reflected by higher HHS and lower WOMAC scores. Hospital stays were also significantly shorter in the AU group. No significant intergroup differences were found for physical activity, pain intensity, or complication rates. The authors' ERAS-based protocol was more effective than standard care in improving functional recovery and reducing length of stay after primary total hip arthroplasty in patients over 65 years of age.

Introduction

Hip osteoarthritis is a major cause of pain and disability in older adults [1]. Surgical treatment is considered when conservative methods fail, with total hip arthroplasty being the definitive option for advanced hip osteoarthritis [2]. Total hip arthroplasty has become the gold standard for treating advanced degenerative changes, primarily indicated for severe pain that significantly reduces quality of life [2]. This procedure yields excellent results, with systematic reviews and registry-based analyses reporting long-term implant survival exceeding 90% at 15 years [3].

Primary arthroplasty in elderly patients requires a highly individualised approach because they often present with multiple comorbidities [4, 5]. Consequently, total hip arthroplasty is a major surgical intervention associated with potential complications [4]. Over the years, perioperative care standards have evolved to improve surgical outcomes. The Enhanced Recovery After Surgery protocol was introduced to standardise and optimise perioperative care, and it has subsequently been adapted to hip and knee arthroplasty [5–7]. The objective of this study was to evaluate the efficacy of a perioperative protocol based on Enhanced Recovery After Surgery principles implemented at our institution, compared to standard care.

Aim of the research

The study aimed to assess the benefits of this structured approach, specifically in improving functional outcomes and reducing hospital stays for patients over 65 years of age undergoing primary total hip arthroplasty.

Material and methods

Aim of the study and research questions

The aim of this study was to evaluate the effectiveness of the authors' perioperative management protocol in patients over 65 years of age undergoing

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Table 1. Study research questions

1. Did the authors' perioperative management protocol have a significantly greater effect on the functional status of the studied patients compared with the standard protocol?
2. Did the authors' perioperative management protocol have a significantly greater effect on the physical activity of the studied patients compared with the standard protocol?
3. Did the authors' perioperative management protocol significantly affect the pain level of the studied patients compared with the standard protocol?
4. Did the authors' perioperative management protocol significantly shorten the length of hospital stay compared with the standard protocol?
5. Did the authors' perioperative management protocol significantly affect the frequency of postoperative complications?

Table 2. Distribution of sex in the study population by group

Sex	ST Group		AU Group		Total	
	N	%	*N*	%	*N*	%
Women	72	59.5	152	63.07	224	61.87
Men	49	40.5	89	36.93	138	38.13
Total	121	100.0	241	100.0	362	100.0

Comparison between groups: p = 0.50986. N – the number of observations.

hip arthroplasty. In connection with the above aim, the following research questions were formulated (Table 1).

Characteristics of the study subjects

A total of 362 individuals were included in the study. The patients were divided into two groups. Bioethics Committee approval was not required. The protocols implemented during the research, both standard and the authors', constituted patient management models commonly used in orthopaedic wards and models compiled from various standard orthopaedic management procedures. The authors' protocol did not involve any additional invasive procedures compared with the standard protocol. During the qualification process for the surgery, each patient was thoroughly informed about the procedure and provided written informed consent for the surgical intervention and associated management.

The following inclusion and exclusion criteria were established for the study. Inclusion criteria included age 65 years and older, qualification for surgery due to hip osteoarthritis or avascular necrosis of the femoral head, and first arthroplasty within the joints of the lower limbs. Exclusion criteria were as follows: age under 65 years, qualification for surgery due to femoral neck fracture, concomitant arthrosis of other joints, including the contralateral hip, that could affect the rehabilitation process, and previous arthroplasty within the joints of the lower limbs.

Patients were not randomised. Two consecutive cohorts operated on in a single department were compared before and after protocol implementation: the ST group (121 patients, 2013–2014) and the AU group (241 patients, 2015–2016). Allocation was determined solely by the date of surgery; neither the surgeon nor the patient influenced group assignment. All patients were operated on by the same team via an anterolateral approach, and both groups followed an identical inpatient physiotherapy programme.

In the ST group, women accounted for 59.5%, whereas in the AU group, women accounted for 63.07%. Sex was not a factor that significantly differentiated the patients in the two groups ($p = 0.50986$) (Table 2).

Individuals in both groups exhibited very similar morphological characteristics regarding age, body height, body weight, and BMI. No statistically significant differences were observed between the analysed indicators in the two study groups (Table 3).

Patients included in the study underwent primary total uncemented hip arthroplasty, primary total cemented hip arthroplasty, or primary hybrid hip arthroplasty in which one component was fixed with cement and the other without cement. In both study groups, uncemented prostheses were implanted most frequently, representing 70.24% of all prostheses in the ST group and 73.03% in the AU group (Table 4).

The most frequently used uncemented acetabular component in both groups was the Plasmacup SC Aesculap cup, accounting for 43.37% of all implanted cups. Among the cemented cups, the Contemporary Stryker cup was implanted most often, representing 19.06% of all cups (Table 5).

Among the implanted stems, the uncemented Bicontact S Aesculap implants were the most numerous, accounting for 38.95% of all stems. The Exeter Stryker implant was the most frequently used cemented stem, representing 23.48% (Table 6).

Table 3. Characteristics of selected anthropometric indicators in the studied patients

Parameter	ST Group (*N* = 121)				AU Group (*N* = 241)				Comparison between groups
	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	
Age [years]	72.752	5.701	65	90	73.888	5.630	65	90	$p = 0.038023$
Body height [m]	1.684	0.069	1.53	1.86	1.682	0.072	1.53	1.88	$p = 0.380979$
Body weight [kg]	72.96	12.295	51	104	72.11	11.721	49	104	$p = 0.337941$
BMI [kg/m²]	25.678	3.822	18.069	35.154	25.378	2.806	18.670	33.251	$p = 0.444469$

N – sample size, $\bar{x}$ – arithmetic mean, Min – minimum, Max – maximum, SD – standard deviation, p – the significance level of differences.

Table 4. Number of uncemented, cemented, and hybrid prostheses performed in both study groups

Type of prosthesis	ST Group		AU Group		Total	
	N	%	*N*	%	*N*	%
Uncemented	85	70.24	176	73.03	261	72.1
Cemented	35	28.92	60	24.9	95	26.24
Hybrid	1	0.83	5	2.07	6	1.66
Total	121	100.0	241	100.0	362	100.0

N – the number of observations.

Table 5. Implanted acetabular components in both study groups

Type of prosthesis	Cup name	ST Group		AU Group		Total	
		N	%	*N*	%	*N*	%
Uncemented	Plasmacup SC Aesculap	55	45.45	102	42.32	157	43.37
	Screw cup Aesculap	4	3.31	5	2.07	9	2.49
	Exeed ABT Biomet	5	4.13	15	6.22	20	5.52
	Rimcup Biomet	22	18.18	59	24.48	81	22.38
Cemented	Contemporary Stryker	14	11.57	55	22.82	69	19.06
	High Wall Stryker	12	9.92	5	2.07	17	4.7
	PE-Cup Aesculap	9	7.44	0	0	9	2.49

N – the number of observations.

Table 6. Type of implanted femoral components in both study groups

Type of prosthesis	Stem name	ST Group		AU Group		Total	
		N	%	*N*	%	*N*	%
Uncemented	Bicontact S Aesculap	53	45.45	88	36.51	141	38.95
	Bicontact H Aesculap	5	3.31	12	4.98	9	4.7
	Bicontact SD Aesculap	1	4.13	2	0.83	3	0.83
	Taperloc Short Biomet	26	18.18	74	30.7	100	27.62
Cemented	Exeter	25	11.57	60	24.9	85	23.48
	Centrament Aesculap	11	9.92	5	2.07	16	4.42

N – the number of observations.

Perioperative management protocols

Standard management protocol

Between 2013 and 2014, patients operated on at the Clinical Department of Orthopaedics and Rehabilitation of the University Hospital in Krakow were managed according to generally accepted principles for major surgical procedures. During the first visit, the patient was qualified for surgery by an orthopaedic surgeon based on medical history, clinical examination, and radiographic findings. Patient education was limited to an oral explanation of the nature of the procedure, possible complications, and postoperative management. Depending on the presence of comorbidities, appropriate specialist consultations were ordered, along with dental and general practitioner consultations. A few days before the procedure, the patient presented for blood collection for necessary laboratory tests. The results of blood tests, ECG, radiographs, and ordered consultations formed the basis for the patient's qualification for surgery by the anaesthesiologist. Admission to the hospital occurred on the day preceding the surgery date. No medications reducing bleeding or wound infiltration anaesthesia were used during the procedure. Multimodal analgesia was not utilised in postoperative management. Drain removal and patient mobilisation occurred on the first postoperative day. It was assumed that the patient's stay in the ward would typically last 5 to 7 days.

Postoperative rehabilitation was initiated on the first postoperative day and included respiratory exercises, isometric and active lower-limb exercises, progressive verticalisation, gait training with crutches, and stair-climbing training before discharge [8, 9].

Authors' management protocol

Beginning in 2015, patients undergoing hip arthroplasty were managed according to the authors' protocol developed based on Enhanced Recovery After Surgery principles [5–7]. The authors' protocol consisted of three parts covering preoperative, perioperative, and postoperative management.

The first visit took place up to 2 years before the planned surgery date, which resulted from the maximum waiting time for the procedure. During the visit, the orthopaedic physician took a detailed medical history and conducted an orthopaedic examination. Radiographs of the hip joints in the anteroposterior projection including one half of the femurs were obtained, and in doubtful cases an axial projection was also performed. If the physician determined that the history, clinical examination, and radiographs qualified the patient for surgery, a detailed conversation about the operation commenced. The benefits of the procedure, possible limitations, and the risk of complications were presented during this conversation. The patient was informed that this was a major surgical procedure carrying a risk of complications, including death, although it yielded very good results. The patient had the opportunity to ask questions and present their doubts. Structured preoperative education may reduce anxiety, improve expectations, shorten hospital stay, and support earlier recovery after hip or knee arthroplasty [10–12]. Another element of the first visit was providing each patient qualified for the surgical procedure with a detailed written checklist of activities before the surgery (Table 7).

Additionally, during the first visit, written information for the primary care physician regarding the planned operation was provided. In addition to information about the planned surgical procedure, this document contained a list of factors identified so far that could negatively affect the course of the procedure and required elimination or modification. Modifiable perioperative risk factors, including obesity and anaemia, were identified and optimised before surgery when possible [13–15]. Other conditions required specialist consultations, especially cardiovascular diseases, oral infections, and gynaecological conditions.

The second visit took place 6 weeks before the planned surgical procedure. During this meeting, the attending physician assessed the patient's state of preparation for the surgery. It was checked whether the patient, under the supervision of the general practitioner and specialists, had eliminated or modified risk factors that could lead to disqualification from the procedure. Hepatitis B vaccinations were also verified. Additionally, the process of the surgical procedure from the time of admission to the hospital the day before the planned surgery to the time of discharge, as well as postdischarge care, was discussed in detail. The benefits of the procedure, limitations, and possible complications were discussed once again. The patient again received information on what to acquire before the surgery, such as crutches, compression stockings, and anti-slip socks. Information was also provided on how to prepare the home environment for their return, such as bathroom adaptation, high seats, and grabbers for lifting small objects. The necessity of general rehabilitation aimed at maintaining good conditions for postoperative recovery was also explained [8, 11].

The third visit took place 2 weeks before the planned operation. During this visit, blood was drawn for basic laboratory tests such as complete blood count, sodium, potassium, APTT, INR, anti-HCV, and HBsAg. Additionally, the patient was examined by an anaesthesiologist, and the results of laboratory tests, ECG, chest radiograph, the opinion of the general practitioner, and specialist consultations were thoroughly analysed. If the patient qualified for the procedure, the optimal type of anaesthesia was selected. The preferred type of anaesthesia was spinal anaesthesia [16, 17].

Table 7. List of activities preparing the patient for hip arthroplasty surgery

Sec	Item	Description
A	1	Hepatitis B vaccination series. Vaccination, including any additional required doses, is to be prescribed by the general practitioner.
	2	Consultation with the general practitioner confirming the absence of contraindications to surgical treatment and providing any therapeutic recommendations for the period of hospitalisation in the clinic. If necessary, the general practitioner refers the patient for specialist consultation.
	3	Specialist consultations confirming the absence of contraindications to surgical treatment and providing any therapeutic recommendations for the period of hospitalisation in the clinic, including diabetologist, endocrinologist, cardiologist, rheumatologist, vascular surgeon, or another specialist depending on clinical need.
	4	Discontinuation of certain medications in consultation with the attending physician or anaesthesiologist. This applies particularly to anticoagulants and nonsteroidal anti-inflammatory drugs.
	5	Dental consultation to exclude chronic inflammatory foci within the oral cavity, including a panoramic dental radiograph.
B		Approximately 2 weeks before arthroplasty, the patient is asked to report to the clinic for an anaesthesiology consultation and to establish any preoperative anaesthesiology recommendations. The appointment is scheduled by telephone.
C		The patient should bring to the hospital all available medical documentation concerning hip osteoarthritis as well as medical documentation describing current and past illnesses.
D		Documents required at admission: a valid identity card and a document or certificate confirming entitlement to free healthcare services.
E		During the hospital stay, the patient should have the following: elbow crutches, a towel, toiletries, pyjamas, and anti-slip socks.

Perioperative management

Perioperative management covered the time from admission to the hospital to discharge from the hospital.

Day of admission. Each patient was admitted to the hospital the day before the surgery. On the day of admission, each patient was examined once again by the orthopaedic physician and the anaesthesiologist to identify any potential abnormalities and react accordingly. During the orthopaedic examination, the HHS, WOMAC, PASE, and NRS scales were completed. In addition, the patient was weighed and measured, and the current BMI value was calculated. In the evening hours, the first dose of low-molecular-weight heparin consisting of 40 mg of enoxaparin was administered subcutaneously as antithrombotic prophylaxis. The patient received subsequent doses at the same time for 4 consecutive weeks, initially during the hospital stay and later at home.

Day of surgery. Prophylactic perioperative antibiotic therapy was administered on the day of the procedure. Standard administration included a first-generation cephalosporin antibiotic, cefazolin, in 3 doses of 1.0 g given every 8 hours, with the first dose administered 30 minutes before the start of the procedure. In cases of a confirmed allergy to β-lactam antibiotics, clindamycin in 3 divided doses of 600 mg within 24 hours was used for antibiotic prophylaxis. Clear fluids were allowed up to 2 hours and solid food up to 6 hours before surgery. Active patient warming systems were implemented throughout the stay in the operating room to prevent the potentially adverse phenomenon of hypothermia [6].

Once the patient was anaesthetised using the previously chosen method, they were positioned on their side, and limb length was checked again. It was important that the operating table was positioned parallel and the frontal plane perpendicular to the operating room floor. Incorrect patient positioning could result in faulty implantation of the prosthesis components and could cause limb length discrepancies. At this point, the patient received one ampoule of Exacyl intravenously.

Before suturing began, thorough irrigation with Betadine and careful haemostasis were performed, after which a drain was placed into the hip joint. The final stage of the surgical procedure was layered suturing. First, the attachment of the gluteal muscles was reconstructed using Novosyn 0 or Vicryl 0 sutures, and then the fascia lata was sutured using Novosyn 2 or Vicryl 2, followed by the subcutaneous layer using Novosyn 2-0 or Vicryl 2-0. At this stage, soft tissues were infiltrated with lidocaine and bupivacaine for

local anaesthesia. Finally, skin sutures were applied, either in the classic form of a nonabsorbable monofilament suture such as Premilene 2-0, Monosoft 2-0, or Prolene 2-0, or in the form of automatic metal staples. Metal staples were not used in patients allergic to nickel. The drain was secured to the skin with the same nonabsorbable monofilament suture used for skin suturing. After suturing the wound, the surgical field was washed and dried, and then a sterile dressing was applied. Following the procedure, the patient returned to their hospital room, where they remained in bed until the next day. Multimodal analgesia was used to treat postoperative pain, in accordance with ERAS principles [7]. A control complete blood count was also performed to detect any potential anaemia at an early stage and quickly implement appropriate treatment.

Postoperative management

Postoperative management covered the time from the first postoperative day to the day of patient discharge from the hospital.

First postoperative day. During this day, the dressing and drain were removed, and a new sterile dressing was applied. A control radiograph was also performed, and postoperative rehabilitation commenced. The course of the entire postoperative rehabilitation was identical to that for patients managed according to the standard management protocol [8, 9].

Subsequent postoperative days. During the hospital stay, the condition of the dressing was monitored, and it was changed if necessary. The proper healing of the wound was also evaluated. The patient's progress in the rehabilitation process was monitored as well.

Discharge day. The patient was discharged from the hospital if they were independently able to stand up and lie down in bed, independently dress and undress, and independently walk with crutches, including walking up and down stairs. The patient received an information card containing instructions for further management, and a prescription for antithrombotic medications, analgesics, and anti-oedema drugs.

Control visits. The patient attended a control visit to remove sutures on the 10th to 12th day after the procedure, and then 6 weeks after the surgery. During these visits, proper wound healing and progress in rehabilitation were assessed. During the visit at 6 weeks, discontinuation of elbow crutches was recommended, and the management plan until the next visit, scheduled one year after the procedure, was discussed again.

Key ERAS components applied in the AU group (absent in the ST group).

Preoperative: structured education at three visits (24 months, 6 weeks, and 2 weeks before surgery) using diagrams, photographs, and video; written checklist for the patient and a written referral for the primary care physician listing modifiable risk factors (smoking, obesity, alcohol, malnutrition, anaemia); HBV vaccination; anaesthetic assessment 2 weeks before surgery with spinal anaesthesia preferred; chlorhexidine bath the evening before surgery. Intraoperative: shortened fasting (clear fluids 2 hours, solids 6 hours), premedication, cefazolin prophylaxis, active warming, intravenous tranexamic acid 1 g, and local infiltration analgesia with lidocaine and bupivacaine. Postoperative: multimodal analgesia, drain removal and mobilisation on day 1, identical physiotherapy in both groups, and function-based discharge criteria (independent transfers, dressing, walking with crutches, and stair climbing). The ST group received oral information only, no antifibrinolytic or infiltration analgesia, and no multimodal analgesia, with a planned stay of 5–7 days.

Tools for assessing results

The following scales were used to evaluate the obtained results:

- HHS (Harris Hip Score) to assess the functional level of patients.
- WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) to assess the functional level of patients.
- PASE (Physical Activity Scale for the Elderly) to assess the physical activity level.
- NRS (Numeric Rating Scale) to assess the severity of pain symptoms.

The following were also evaluated: the length of the patient's hospital stay, and the number of intraoperative and postoperative complications, both orthopaedic and general.

All measurements were taken twice for each patient in both study groups. The first measurement was taken before the surgical procedure, and the second was taken 12 months after the surgical procedure. In the case of assessing the number of postoperative complications, the second measurement took place 30 days after the procedure.

HHS (Harris Hip Score) Scale

The Harris Hip Score assesses pain, function, deformity, and range of motion, with higher scores indicating better hip function [18, 19]. The maximum possible score is 100. Results are interpreted as follows: a score below 70 indicates a poor result, 70 to 80 indicates moderate, 80 to 90 indicates good, and 90 to 100 indicates a very good result [18, 19].

WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) Scale

The WOMAC is one of the most frequently used questionnaires in assessing musculoskeletal disor-

Table 8. Comparison of HHS values before and after the surgical procedure in both study groups

Group	HHS before surgery					HHS after surgery					Comparison between measurements
	N	$\bar{x}$	SD	Min	Max	*N*	$\bar{x}$	WSD	Min	Max	*P*-value
ST group	121	34.34	7.76	20	56	121	89.69	4.06	75	98	0.000008
AU group	241	34.15	7.67	20	55	241	93.14	4.38	83	100	0.000008

Comparison between groups: before surgery p = 0.995039; after surgery p = 0.000102. N – the number of observations, $\bar{x}$ – arithmetic mean, Min – minimum, Max – maximum, SD – standard deviation, p – the significance level of differences.

Table 9. Comparison of WOMAC values before and after the surgical procedure in both study groups

Group	WOMAC before surgery					WOMAC after surgery					Comparison between measurements
	N	$\bar{x}$	SD	Min	Max	*N*	$\bar{x}$	SD	Min	Max	*P*-value
ST group	121	54.96	7.91	34	70	121	10.02	4.58	0	21	0.000008
AU group	241	54.80	7.94	20	55	241	7.25	4.13	0	24	0.000008

Comparison between groups: before surgery p = 0.997466; after surgery p = 0.003923. N – the number of observations, $\bar{x}$ – arithmetic mean, Min – minimum, Max – maximum, SD – standard deviation, p – the significance level of differences.

ders. The patient can complete the questionnaire independently, evaluating pain severity, stiffness, and physical function in 24 questions. Pain severity is assessed through 5 questions, stiffness through 2 questions, and physical functioning through 17 questions. The test questions are rated on a scale of 0 to 4, where 0 indicates no symptoms and 4 indicates extreme symptoms. The maximum possible number of points is 96, with higher scores indicating greater pain, stiffness, and functional limitations [20, 21].

PASE (Physical Activity Scale for the Elderly)

The Physical Activity Scale for the Elderly is a brief (approximately 5 minutes) and easy-to-score survey specifically designed to assess physical activity in studies of individuals aged 65 years and older [22]. PASE examines occupational, household, and recreational activities over the previous week, with higher scores indicating greater physical activity [22, 23].

NRS (Numeric Rating Scale)

The Numeric Rating Scale assesses pain intensity from 0 to 10, with 0 indicating no pain and 10 indicating the worst imaginable pain [24].

Statistical analysis

Statistical analysis was performed using Statistica 13.5 PL software. Descriptive statistics were calculated for all variables, and they are presented as mean, median, minimum, maximum, quartiles, and standard deviation, as appropriate. The normality of data distribution was assessed using the Shapiro-Wilk test. For comparisons between groups, either Student's *t*-test or the Mann-Whitney *U* test was used, depending on data distribution. In this case, Student's *t*-test was used for comparison. Changes over time were analysed using repeated-measures analysis of variance (ANOVA) or the Wilcoxon signed-rank test, where appropriate. Categorical variables were compared using the χ^2 test. The significance level was established at $p < 0.05$. Between-group differences are reported as mean differences with 95% confidence intervals and Cohen's *d*. Because of the low number of complications, categorical comparisons were performed with Fisher's exact test.

Results

Assessment using the HHS scale

In both the ST group and the AU group, there was a statistically significant increase in the mean HHS values after the surgery compared to the preoperative values. It should be noted, however, that in the AU group, the increase in these HHS values was greater, and the difference between the groups after the surgery was statistically significant, indicating greater effectiveness of the proprietary management protocol; mean difference 3.45 points (95% CI: 2.54–4.36; $d = 0.81$) (Table 8).

Assessment using the WOMAC scale

In both the ST group and the AU group, there was a statistically significant decrease in the mean WOMAC values after the surgery compared to the preoperative values. However, in the AU group, the decrease in these values was greater, and the difference between the groups after the surgery was statistically significant, indicating greater effectiveness of the proprietary management protocol; mean difference 2.77 points (95% CI: 1.80–3.74; $d = 0.65$) (Table 9).

Table 10. Comparison of PASE values before and after the surgical procedure in both study groups

Group	PASE before surgery					PASE after surgery					Comparison between measurements
	N	$\bar{x}$	SD	Min	Max	*N*	$\bar{x}$	SD	Min	Max	*P*-value
ST group	121	115.6	28.7	64	180	121	138.4	29.6	87	204	< 0.000001
AU group	241	124.4	30.6	62	180	241	146.3	30.4	76	210	< 0.000001

Comparison between groups: before surgery p = 0.008; after surgery p = 0.018. N – the number of observations, $\bar{x}$ – arithmetic mean, Min – minimum, Max – maximum, SD – standard deviation, p – the significance level of differences.

Table 11. Comparison of NRS values before and after the surgical procedure in both study groups

Group	NRS before surgery					NRS after surgery					Comparison between measurements
	N	$\bar{x}$	SD	Min	Max	*N*	$\bar{x}$	SD	Min	Max	*P*-value
ST group	121	6.74	1.95	4	10	121	0.18	0.39	0	1	p = 0.000000
AU group	241	6.59	2.24	3	10	241	0.12	0.33	0	1	p = 0.000000

Comparison between groups: before surgery p = 0.14935; after surgery p = 0.09215. N – the number of observations, $\bar{x}$ – arithmetic mean, Min – minimum, Max – maximum, SD – standard deviation, p – the significance level of differences.

Table 12. Length of hospital stay after the surgical procedure for patients from both study groups

Group	Length of stay [days]					Comparison between groups
	N	$\bar{x}$	SD	Min	Max	*P*-value
ST group	121	6.98	0.96	5	9	< 0.001
AU group	241	3.91	1.09	2	7	

N – the number of observations, $\bar{x}$ – arithmetic mean, Min – minimum, Max – maximum, SD – standard deviation, p – the significance level of differences.

Assessment using the PASE scale

A statistically significant increase in mean PASE scores was observed in both groups between measurements ($p < 0.001$). The AU group scored higher than the ST group both before (mean difference: 8.8 points; 95% CI: 2.4–15.2; $p = 0.008$) and after surgery (7.9 points; 95% CI: 1.4–14.4; $p = 0.018$), indicating a baseline imbalance in physical activity between the cohorts. However, the magnitude of improvement was almost identical in both groups (ST +22.8 vs. AU +21.9 points), indicating similar effectiveness of both management protocols in increasing physical activity (Table 10).

Assessment using the NRS scale

In both study groups, a statistically significant difference in the mean NRS value was obtained between the measurements. No significant difference was observed between the two groups, indicating similar effectiveness of both management protocols in reducing the intensity of pain symptoms in the studied individuals; mean difference 0.06 points (95% CI: −0.02 to 0.14; $d = 0.17$) (Table 11).

Assessment of the length of hospital stay

Analysing the number of days spent in the hospital by patients from both study groups, a significantly shorter stay was noted in individuals from the AU group compared to individuals from the ST group, indicating greater effectiveness of the proprietary management protocol in shortening hospitalisation time; mean difference 3.07 days (95% CI: 2.85–3.29; $d = 2.93$) (Table 12).

Assessment of the number of postoperative complications

In both study groups, a small number of complications related to joint arthroplasty was recorded. The percentage of these complications was lower in the AU group, but the differences in their incidence between the groups were not statistically significant (Table 13).

Similar to orthopaedic complications, a small number of general complications was also recorded in both study groups. The percentage of these complications was lower in the AU group, but the differences in their incidence between the groups were not statistically significant (Table 14).

Table 13. Early and late complications directly related to hip arthroplasty in patients from both study groups

Type of complication	ST group (*N* = 121) *N*	ST group (*N* = 121) %	AU group (*N* = 241) *N*	AU group (*N* = 241) %	Comparison between groups	Timing
Impaired wound healing requiring revision	2	1.65	3	1.24	$p = 0.2$	Early (during hospital stay)
Periprosthetic fracture (intraoperative)	1	0.83	2	0.83	$p = 0.7$	Early (during hospital stay)
Total early	3	2.48	5	2.07	$p = 0.1$	Early (during hospital stay)
Dislocation of the prosthesis	1	0.83	1	0.41	$p = 0.232$	Late (up to 30 days after surgery)
Periprosthetic fracture	1	0.83	1	0.41	$p = 0.2$	Late (up to 30 days after surgery)
Prosthetic joint infection	2	1.65	2	0.83	$p = 0.03$	Late (up to 30 days after surgery)
Heterotopic ossification	1	0.83	1	0.41	$p = 0.2$	Late (up to 30 days after surgery)
Death	0	0	0	0		Late (up to 30 days after surgery)
Total late	5	4.13	5	2.06	$p = 0.02$	Late (up to 30 days after surgery)

Table 14. General complications in patients from both study groups up to 30 days after the procedure

Type of complication	ST group (*N* = 121) *N*	ST group (*N* = 121) %	AU group (*N* = 241) *N*	AU group (*N* = 241) %	Comparison between groups
Myocardial infarction	2	1.65	2	0.83	$p = 0.03$
Acute kidney failure	2	1.65	1	0.83	$p = 0.03$
Stroke	1	0.83	1	0.41	$p = 0.2$
Deep vein thrombosis	1	0.83	1	0.41	$p = 0.2$
Bleeding from the upper or lower gastrointestinal tract	1	0.83	1	0.41	$p = 0.2$
Pneumonia	1	0.83	1	0.41	$p = 0.2$
Pulmonary embolism	1	0.83	1	0.41	$p = 0.2$

Discussion

Total hip arthroplasty is the most commonly performed surgical procedure for the treatment of degenerative hip disease. It relieves pain and enables patients to return to daily activities. A painless and functional hip improves quality of life in both subjective and objective terms. Even impairment of one hip joint negatively affects daily functioning and may limit occupational activity and social participation; therefore, rapid recovery is of major importance [1, 2]. As a result, total hip arthroplasty has become one of the most common orthopaedic procedures. Despite the routine nature of the operation, it remains challenging because of the high expectations of older patients regarding postoperative mobility and independence. One strategy to improve this situation is the ERAS protocol, increasingly used in hip and knee arthroplasty [5–7].

One of the best documented benefits of ERAS is shortening of hospital stay. A shorter stay reduces the risk of hospitalisation-related complications and provides economic benefits for hospitals. Although the reported magnitude of reduction varies, the literature consistently supports the effectiveness of ERAS in this respect. Ripollés-Melchor *et al.* [25], in a study of 6146 patients, demonstrated a statistically significant reduction in length of stay, with ERAS patients staying on average 1 day less. Larsen [26], in a group of 247 patients after primary total hip or knee arthroplasty, observed a significant reduction of 4 days. Den

Hartog *et al.* [27], comparing three groups of patients treated in Dutch orthopaedic departments between 2008 and 2012, found a statistically significant reduction in mean length of stay from 4.6 to 2.9 days only in the group managed fully according to ERAS. Husted *et al.* [28] showed that in Denmark, between 2000 and 2009, the annual number of arthroplasties nearly doubled, while hospital stay decreased from 10 to 11 days to 4 days. The present study is consistent with these reports. The mean hospital stay in the group managed according to the authors' ERAS-based protocol was almost twice as short as in the standard protocol group, and this difference was statistically significant.

The ERAS-related reduction in hospital stay is commonly attributed to early mobilisation, prompt verticalisation, structured rehabilitation, and patient education [8, 11, 28–30]. In the present study, both groups followed the same rehabilitation program, whereas the group treated according to the authors' ERAS-based protocol received substantially broader education supported by various materials, including diagrams and photographs. This may explain the significantly shorter hospitalisation observed in that group.

Another important measure of perioperative effectiveness is the number and type of postoperative complications, both early complications observed during hospitalization and later complications occurring up to 30 days after surgery. The literature discusses this issue extensively, but the conclusions are not uniform. The systematic review by Nicholson *et al.* [31], which included more than 200 scientific articles, indicated a statistically significant reduction in the risk of late complications within 30 days after surgery in patients managed according to ERAS. However, this review included all surgical specialties, not only orthopaedics, which may have influenced the results. Barbieri *et al.* [32], in a meta-analysis focused specifically on arthroplasty, also reported a statistically significant reduction in complications with ERAS compared with standard care. By contrast, Gwynne-Jones *et al.* [30], who analysed outcomes in more than 1000 patients, found no statistically significant difference in postoperative complications between ERAS and standard care groups. The most frequent complications included prosthetic dislocation, infection, and wound-healing problems. Similarly, Larsen [26], in 247 patients undergoing hip or knee arthroplasty, found no association between the protocol used and the number of postoperative complications. Husted *et al.* [28], in 1731 patients after primary hip or knee arthroplasty, also found that ERAS did not reduce readmissions related to postoperative complications. The most frequent complications included prosthetic dislocation, wound infection, myocardial infarction, and stroke. Nicholson *et al.* [31] reached a similar conclusion, as their systematic review did not demonstrate a greater effectiveness of ERAS than standard care in reducing readmissions due to postoperative complications. The present findings are in line with these reports. Although the percentage of complications was lower in the group managed with the authors' ERAS-based protocol, the differences were small and not statistically significant. This applied to both orthopaedic complications directly related to arthroplasty and general complications.

Pain is an inherent consequence of surgery and an important determinant of recovery. Pain may occur immediately after surgery and may also persist or recur later. However, the literature contains relatively few studies assessing the relationship between ERAS and pain intensity. Existing reports mainly describe ERAS-recommended multimodal analgesia in the early postoperative period [7]. An exception is the study by Leiss *et al.* [33], which demonstrated a statistically significant reduction in pain intensity at 4 and 12 months after surgery. However, that analysis concerned only patients treated according to ERAS and was based on the VAS scale. The present study both confirms and extends these findings. Pain intensity was assessed with the more precise NRS scale, and a comparative analysis between two treatment protocols was performed. Pain decreased significantly in both groups, but the intergroup analysis did not show a statistically significant difference, indicating similar effectiveness of the ERAS-based and standard protocols in reducing pain up to a year after surgery.

Functional status is another major outcome after lower-limb orthopaedic procedures. It is closely related to patient expectations, satisfaction with treatment, and quality of life. The literature contains relatively few reports assessing functional outcomes in relation to ERAS. Most studies focus on length of stay, postoperative complications, costs, or occasionally quality of life. Again, the main exception is the study by Leiss *et al.* [33], which assessed function at 4 and 12 months after surgery using the HHS and WOMAC scales. According to these authors, ERAS significantly improved function in 109 patients after hip surgery. However, their analysis had an important limitation: the absence of a control group. This makes it impossible to assess ERAS against another treatment protocol. The present study helps fill this gap. Functional status was assessed in both groups using both HHS and WOMAC. A statistically significant improvement was observed in both groups, which supports the literature. However, intergroup analysis showed significantly better postoperative functional outcomes in the group managed according to the authors' ERAS-based protocol, indicating its greater effectiveness in improving functional status.

Despite the high frequency of lower-limb arthroplasty, physical activity is rarely analysed in this context. This issue is important because patients increasingly expect not only independence in basic daily activities but also freedom from limitations in recreational and occupational activities, both of which

depend on overall physical fitness. Reports on physical activity are also lacking in studies evaluating ERAS. The present study addresses this gap by using the PASE scale. The results showed a statistically significant increase in PASE scores in both groups, indicating improved overall physical fitness after surgery. However, no statistically significant difference was found between the groups, which suggests similar effectiveness of both the authors' ERAS-based protocol and the standard protocol in improving physical activity.

Given population aging and the steadily rising number of arthroplasties performed each year, there is a continuing need to seek more effective solutions that reduce perioperative complications while maximising patient satisfaction and quality of life. ERAS and other protocols developed on the basis of ERAS principles appear promising, but they are not a universal solution to all problems associated with orthopaedic surgery. Further large-scale studies are still needed to better define their strengths and limitations, especially since ERAS remains a relatively new tool and is not yet the universal standard in orthopaedic patient care.

This was a non-randomised, single-centre, before–after study with a historical control group, which precludes causal inference and exposes the results to temporal confounding. The groups differed in size and in mean age ($p = 0.038$), although the AU group was slightly older. Outcome assessors were not blinded, part of the HHS is examiner-rated, and no multivariable adjustment was performed. The number of complications was too low to detect small differences. Data were collected between 2013 and 2016; since then, surgical technique, anaesthesia, and rehabilitation have evolved, and several components of the studied protocol have become routine practice, so the absolute magnitude of the observed benefit may be smaller today. The findings should therefore be interpreted as documenting the effect of implementing a structured perioperative pathway rather than as a comparison with contemporary standard care. Costs and readmissions were not analysed.

Conclusions

The authors' management protocol significantly improved functional status and shortened hospital stay compared with the standard protocol in patients undergoing primary total hip arthroplasty. However, it did not significantly affect physical activity, pain level, or the frequency of postoperative complications.

Funding

No external funding.

Ethical approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

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Received: 16.05.20226
Accepted: 6.08.2026
Online publication: 22.10.2026