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Short-term Pain Outcomes in Robotic versus Manual Total Hip Arthroplasty

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Abstract

Background: Four-hundred-fifty-thousand patients annually undergo total hip arthroplasty (THA) in the United States. THA has been shown to alleviate pain, restore function, and improve quality of life. Manual implant postoperative complications have led to a need for more advanced technology. Robotic assisted THA has the potential for greater accuracy in component positioning compared to manual. Comparing robotic and manual THA, significant differences have been shown in hip-specific functional outcomes, component positioning, complications, and patient-centered outcomes. The effects of these techniques on differences from baseline pain have yet to be investigated.

Methods: A retrospective review of the Berkshire Medical Center electronic medical record system identified 70 patients undergoing THA between March 1, 2020 to October 31, 2021 with preoperative diagnosis of osteoarthritis or degenerative joint disease of the hip. Patients were admitted for at least one day postoperatively with documented preoperative and POD1 vital signs, POD1 pain scores, and LOS were included. The primary objective was to identify differences in postoperative day 1 (POD1) pain scores between robotic and manual THA. The secondary objective was to identify differences in length of stay (LOS) and preoperative versus postoperative vital signs (blood pressure, heart rate) between groups.

Results: A statistically significant difference was identified for postoperative pain scores indicating significantly lower pain scores in patients undergoing manual THA in comparison to robotic (3.0 versus 5.0; $P = 0.01$). No significant differences were identified for systolic blood pressure ($P = 0.46$), diastolic blood pressure ($P = 0.43$), heart rate ($p = 0.93$), or LOS ($P = 0.35$).

Discussion: Previous studies have demonstrated decreases in postoperative pain, LOS, and costs in patients undergoing robotic versus manual THA. The results of our study were not consistent with these studies which may be due to small sample size, quantity of anesthetic used, and surgeon differences. THA performed via robotic technique demonstrated a statistically significant increase in postoperative pain outcomes when compared to manual. There may be a lack of clinical difference in postoperative pain scores between groups and no differences were identified for vital signs or LOS.

Keywords

Total hip arthroplasty, Robotic, Manual, Pain

Conflict of Interest Statement

We do not have conflicts of interest or financial disclosures.

Cover Page Footnote

Special thanks to Paul Johansen, MA, Biostatistician.

ORIGINAL ARTICLE

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1. Introduction

Total hip arthroplasty (THA) is one of the most common orthopaedic surgeries with 450,000 performed annually in the United States.[1] Most of these cases are attributed to osteoarthritis of the hip. Osteoarthritis has been associated with decreased quality of life secondary to pain and loss of function. THA has been shown to alleviate pain, restore function, and improve quality of life. However, implant postoperative complications, including aseptic loosening and component malpositioning associated with manual technique, have led to a need for more advanced technology to improve THA.[2] Robotic assisted technology was first developed in 1992 and is constantly evolving, offering the potential for greater accuracy in positioning of arthroplasty components when compared to manual technique.[2]

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Previous studies have demonstrated statistically significant differences in hip-specific functional outcomes, complications, and patient-centered outcomes when comparing robotic and manual total hip arthroplasty techniques.[2–4] These studies have also shown significant differences in improved patient-reported functional outcomes, improved component positioning, and shortened length of stay. However, studies have not demonstrated statistically or clinically significant differences in general health or patient satisfaction scores.[5–7] Whether robotic THA is effective in reducing postoperative pain, objective changes in vital signs, and length of stay (LOS) in comparison to manual THA remains unclear. The results of this study will allow orthopedic surgeons to better guide their patients and their practice to reduce postoperative pain, stabilize vital signs, and reduce LOS.

The purpose of this study was to assess for any significant differences in postoperative day 1 (POD1) visual analog scale pain scores, blood pressure, heart rate, and LOS between robotic and manual THA. The primary outcome was the difference in patient-reported visual analog pain scores. Secondary outcomes were differences in vital signs (blood pressure, heart rate) and LOS (in days). Due to more precise measurements and less bone removed based on preoperative computed tomography (CT) scan of each patient's unique hip anatomy, it was hypothesized that patients undergoing robotic THA would report less pain, demonstrate less elevation in postoperative vital signs, and have shorter LOS in comparison to manual THA patients.

2. Methods

2.1. Patients

This retrospective cohort study was conducted to investigate the differences in pain outcomes for patients who underwent either robotic (semi-active MAKO Robotic arm Interactive Orthopedic system) or manual THA between March 1, 2020 to October 31, 2021 at Berkshire Medical Center (BMC), in Pittsfield, MA. IRB exemption was obtained. All information was collected from BMC's electronic medical record system. Inclusion criteria for this study were male and female patients aged ≥50-years-old who had undergone robotic or manual THA with a preoperative diagnosis of "osteoarthritis" or "degenerative joint disease" of the hip. If patients underwent separate encounters for THA of bilateral hips, they were included as separate cases. Patients with a preoperative indication for surgery other than osteoarthritis or degenerative joint disease of the hip or were undergoing revision were excluded. Patients who were discharged to home on postoperative day 0 (POD0) were excluded as they would have residual analgesia from regional anesthesia utilized for surgery. Residual analgesia would be present in all patients on POD0 no matter the duration of LOS. Standardized postoperative pain management could impact reported pain levels; however, comparisons made on POD1 were more apt to provide a more accurate indication of pain due to the high degree of analgesia with regional anesthesia.

Patients were stratified into two groups based on the method of arthroplasty they received. The decision of whether a patient would undergo robotic or manual THA was determined through a conversation between the patient and surgeon on the risks and benefits of each procedure, as well as patient-specific factors, such as body habitus that may make one approach more advantageous over another (i.e. posterior approach allows for better visualization in obese patients). Disease severity was not part of the decision process. Each selection was individualized based on the patient's decision for the type of technique they were willing to undergo.

General anesthesia and spinal anesthesia were utilized for both manual and robotic techniques. The decision to provide one type of anesthesia over another was individualized based on patient comorbidities and patient comfort. Regional blocks were not utilized but local anesthetic was used for all patients. It is standard practice at this institution to infiltrate bupivacaine liposomal solution into the pericapsular tissues, as well as deep and superficial musculature, prior to reapproximation of the deep fascia. The remaining local anesthetic was injected into the subcutaneous tissues before closure of the skin. The quantity of anesthetic used was based on volume required to cover the surgical site and individual patient factors with a maximum dose of 266-mg per dose. Postoperative pain management was standardized following a protocol of available analgesics depending on the patient's reported pain level. This pain regimen ranged from acetaminophen or non-steroidal anti-inflammatory agents with mild pain to opioids for severe pain.

Patient records were identified using procedure codes for "total hip arthroplasty" and ICD-10 codes for "osteoarthritis of the hip" or "degenerative joint disease of the hip." Electronic medical records were reviewed to select patients who underwent subsequent THA for this preoperative diagnosis. Selected patient charts were reviewed to record age, sex, race, type of THA performed (robotic versus manual), POD1 vital signs (blood pressure, heart

rate), postoperative visual analog pain scores, and LOS.

2.2. Definitions

Osteoarthritis (degenerative joint disease) of the hip: A noninflammatory degenerative disorder of the hip joint complex. Diagnosis was made through a combination of patient history, clinical features (pain during or after activity alleviated by rest, joint crepitus, restricted range of motion, and morning stiffness lasting >30 min), radiographic evidence of irregular joint space narrowing, subchondral sclerosis, osteophytes, and subchondral cysts.

Manual total hip arthroplasty: Conventional technique for performing total hip arthroplasty using a universal protocol of measurements and cuts.

Robotic total hip arthroplasty: Robotic-assisted technique for performing total hip arthroplasty using the semi-active MAKO Robotic arm Interactive Orthopedic system.

Visual analog pain scale (VAS): For assessment of pain using the visual analog scale, the patient rated their level of pain from 0 to 10 with 0 being no pain and 10 being the maximum intensity of pain.

Length of stay: Number of days in which the patient was admitted to the hospital for total hip arthroplasty.

Blood pressure: Measurement of the difference in blood pressure in the preoperative setting immediately prior to surgery and on postoperative day 1 at 0700 or soon thereafter in order to more accurately compare between participants in robotic versus manual total hip arthroplasty groups. Comparison of postoperative blood pressure to baseline blood pressure allowed for determination of the sympathetic response and its correlation with patient reported visual analog pain scores.

Heart rate: Measurement of the difference in heart rate in the preoperative setting immediately prior to surgery and on postoperative day 1 at 0700 or soon thereafter in order to more accurately compare between participants in robotic versus manual total hip arthroplasty groups. Comparison of postoperative heart rate to baseline blood pressure allowed for determination of the sympathetic response and its correlation with patient reported visual analog pain scores.

2.3. Preoperative planning

All patients undergoing total hip arthroplasty had weight-bearing plain anteroposterior pelvic radiographs utilized by surgeons for preoperative templating. Patients in the robotic total hip arthroplasty group had additional preoperative CT scan of the pelvis and proximal femur. Patient-specific measurements from individual CT scans were used in the MAKOplasty Total Hip Application system (Stryker) for implant positioning.

2.4. Outcomes

The objective of this study was to assess for differences in POD1 visual analog scale pain scores, vital signs, and LOS between robotic versus manual THA. The primary outcome was the difference in the median of patient-reported postoperative visual analog pain scores. Secondary outcomes were the differences in the median of pre- and postoperative vital signs (blood pressure, heart rate) and LOS.

2.5. Statistical analysis

Difference in median values was used for analysis as data were not normally distributed. Continuous data was analyzed with the Kruskal−Wallis test and discrete data was analyzed with the Chi squared test or Fisher's exact test as appropriate. The Kaplan−Meier method was used to analyze time-to-event data. The significance level considered was $P \leq 0.05$. Additionally, interquartile ranges, means, and standard deviations were calculated for between-group comparative analysis.

3. Results

A total of 273 total hip arthroplasties (THA) were performed between March 1, 2020 to October 31, 2021 at BMC. Of the 273 THA cases, 92 had a preoperative diagnosis of unilateral primary osteoarthritis of the hip while the remaining 181 cases with a non-primary osteoarthritis of the hip diagnosis were excluded. Of the remaining 92 patients with a preoperative diagnosis of primary osteoarthritis of the hip, 74 were admitted for greater than or equal to one-day postoperative. The remaining 18 patients were discharged on postoperative day 0 (POD0) and were excluded as pain score data were not available for analysis at this institution. A total of 17 patients within the study period were discharged on POD0, 15 underwent manual THA and 2 underwent robotic THA. The average age of patients discharged on POD0 was 62-years-old, whereas the average age of patients discharged on or after POD1 was 70-years-old. Of the 74 cases with POD1 data, 39 underwent robotic THA and 35 underwent manual THA. The robotic THA group was 66.7% women and the manual THA group was 57.1% women (Fig. 1).

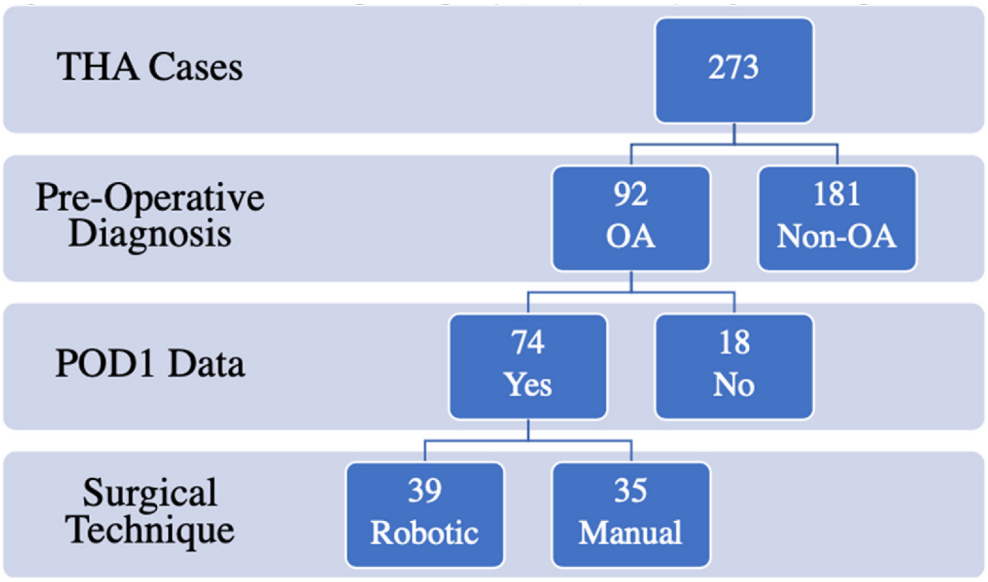

Fig. 1. Distribution of total hip arthroplasty (THA) cases by surgical technique.

Patients who underwent manual technique received the anterior approach with Stryker components. A total of two surgeons performed the manual technique while the robotic technique was performed by two different surgeons. The robotic technique utilized an anterior or posterior approach, depending on the surgeon performing the operation, with Stryker components.

A total of four patients underwent total hip arthroplasty of both hips within 1-year or greater from initial operation. Three of these patients underwent robotic total hip arthroplasty of bilateral hips whereas one patient underwent robotic total hip arthroplasty of the right hip and manual of the left hip. Each of these surgeries was categorized as separate cases in analysis. There were no statistically significant differences in demographic factors between study groups indicating adequate control (Table 1).

Table 1. Patient demographics.

Characteristic	Robotic THA	Manual THA	*p*-value
Hips, No.	35	39	
Patients, No.	32	38	
Age			0.87
Mean + SD	70.3+/11.1	69.8 ± 10.0	
Range	50–89	50–88	
Sex, No.			0.51
Female	20 (57.1%)	26 (66.7%)	
Male	15 (42.9%)	13 (33.3%)	
Race, No.			0.94
White	34 (97.1%)	38 (97.4%)	
Black	1 (2.9%)	1 (2.6%)	
Laterality, No.			0.26
Left	12 (34.3%)	20 (51.2%)	
Right	23 (65.7%)	19 (48.7%)	

Abbreviations: THA, total hip arthroplasty.

3.1. Outcomes

Patients who underwent manual THA had significantly lower postoperative visual analog pain scores in comparison to those who underwent robotic THA (3.0 versus 5.0; P = 0.01; Table 2). Primary outcomes are illustrated in Fig. 2.

There was no difference in length of stay (1.0 versus 1.0; $P = 0.25$) or preoperative versus postoperative vital signs including systolic blood

Table 2. Postoperative outcome measures and differences between groups.

Outcome [Median (1QR)]	Robotic THA	Manual THA	*p*-value	95% CI
Pain	5.0 (3,6.3)	3.0 (2,5)	0.01	(-2.384, −0.252)
Systolic Blood Pressure	−16.0 (−26,5.5)	−15.0 (−30,-0.5)	0.46	(-14.91,5.94)
Diastolic Blood Pressure	−7.0 (−16,2.3)	−9.0 (−19,-2)	0.43	(-9.40, 4.37)
Heart Rate	3.0 (−6,15.3)	2.0 (−4,12)	0.93	(-7.08, 8.91)
Length of Stay	1.0(1,2)	1.0(1,2)	0.25	(-0.663,0.197)

Abbreviations: THA, total hip arthroplasty.
Length of Stay was analyzed using the Kaplan Meier method for time-to-event data.

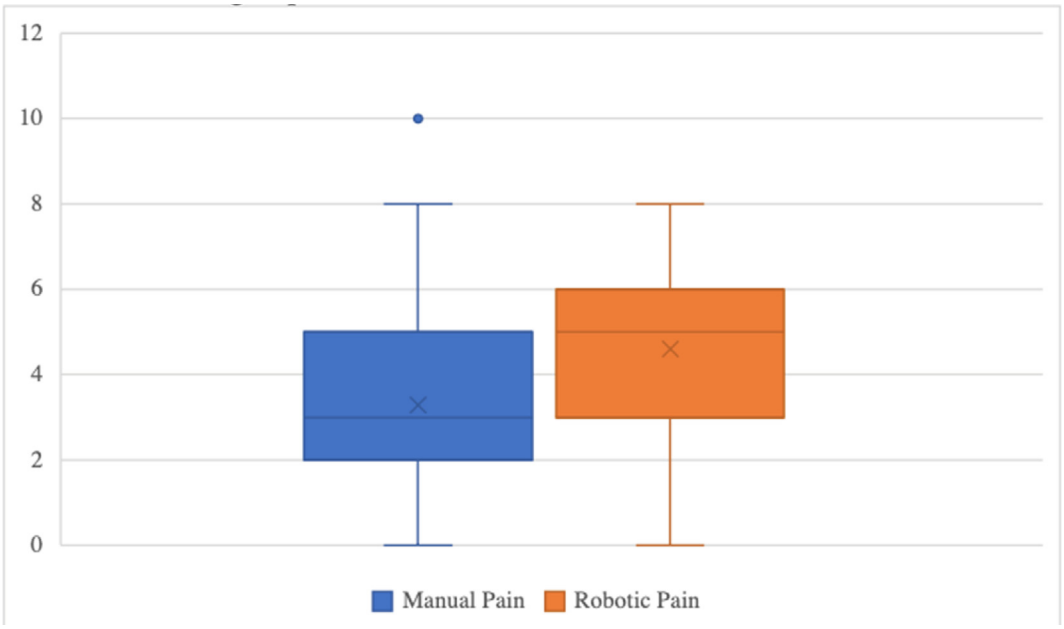

Fig. 2. Difference in postoperative visual analog pain scores between manual and robotic THA groups.

pressure (−15.0 versus −16.0; $P = 0.46$), diastolic blood pressure (−9.0 versus −7.0; $P = 0.43$), or heart rate (2.0 versus 3.0; $P = 0.93$). Secondary outcomes are illustrated in Fig. 3 and Fig. 4.

4. Discussion

This study reported short-term clinical outcomes for patients who underwent robotic THA compared to patients who underwent manual THA. Thirty-five robotic THAs were assessed against thirty-nine manual THAs for differences in outcomes. The findings demonstrated statistically significant higher postoperative pain scores in patients undergoing robotic THA.

We hypothesized that patients undergoing robotic THA would report less pain, demonstrate less

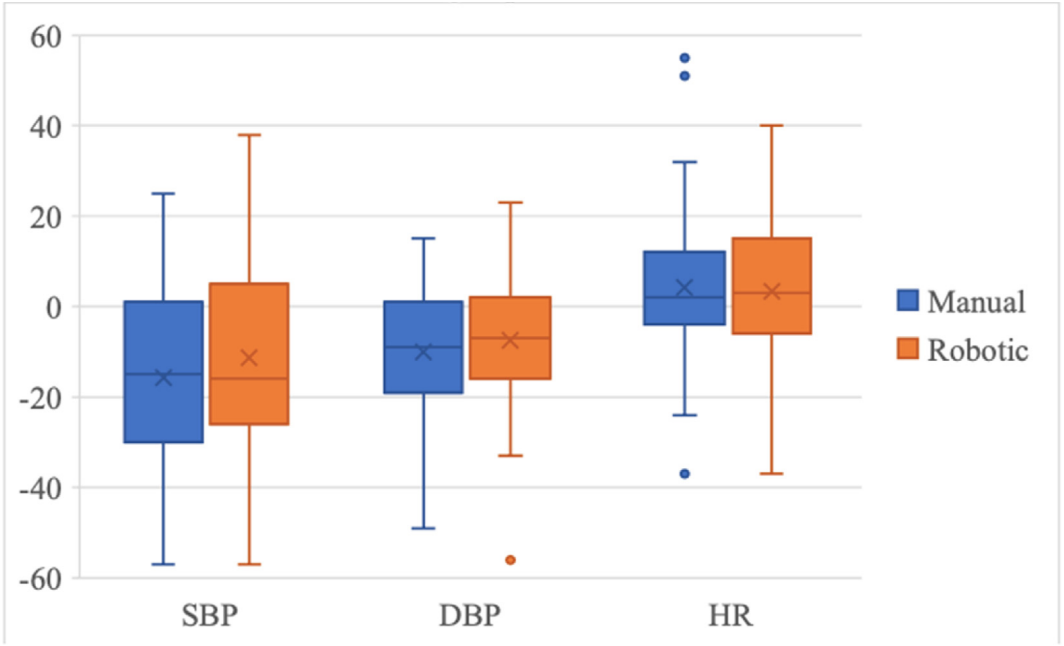

Fig. 3. Comparison of preoperative versus postoperative change in vital signs between manual and robotic THA groups.

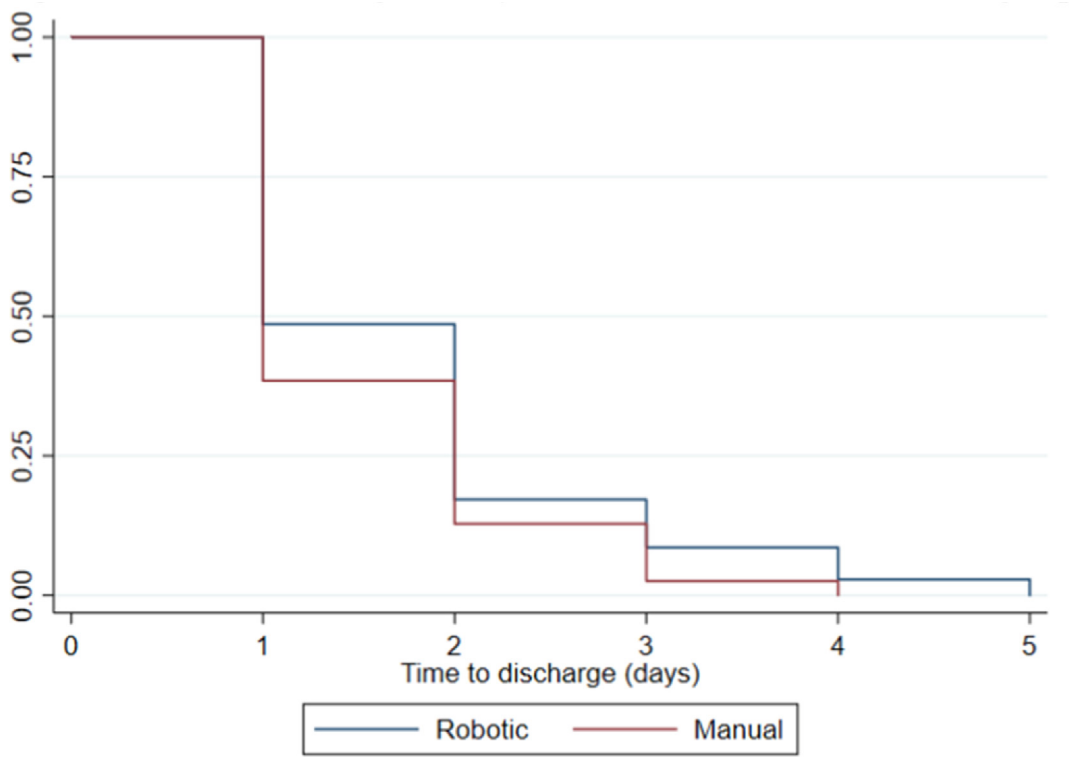

Fig. 4. Difference in length of stay between manual robotic THA groups.

elevation in postoperative vital signs, and have shorter LOS in comparison to manual THA patients due to more precise measurements and less bone removed based on individualized preoperative CT imaging. While postoperative pain management was standardized, subjectively reported pain scores could not be adequately compared between patients due to differences in pain tolerance. This was the reason for utilizing preoperative and postoperative vital signs in combination with patient reported pain scores to provide an objective measure of pain. Although there were multifactorial reasons that could alter vital signs and not solely dependent on pain, the change in preoperative and postoperative vital signs was the most objective measure that could be utilized for comparison of subjective pain levels.

We found that there was a significant difference in postoperative visual analog pain scores favoring the manual THA group (3.0 (IQR 2−5) versus 5.0 (IQR 3−6.3); $P = 0.01$). This study also demonstrated no significant differences in secondary outcomes including LOS and preoperative versus postoperative vital signs. Length of stay was utilized as patients of both groups needed to meet specific criteria in order to be safely discharged. Prior to discharge, patients must have been able to ambulate, climb, and descend stairs with use of an assistive device. Until patients were able to meet these criteria, they could not be discharged. One of the differences in LOS may have been due to differences in pain. Patients with higher levels of pain may have ambulated less frequently than those with less pain. These findings indicate that there is a statistically significant difference in postoperative pain scores between groups. It is unclear if clinical significance is present as both groups underwent a similar analgesia regimen based on subjectively reported pain scores.

Previous studies have demonstrated decreases in postoperative pain, LOS, and costs in patients undergoing robotic THA when compared to manual THA.[2–7] Remily et al.[4] performed a retrospective cohort study to evaluate surgical outcomes in 4630 patients undergoing robotic THA matched to 4630 patients undergoing manual THA over an 8-year period. They demonstrated a significant decrease in LOS and costs favoring the robotic group over the manual group. However, no significant difference in surgical outcome measures was demonstrated between groups.

Clement et al.[2] compared hip-specific functional outcomes and patient satisfaction between 40 patients undergoing robotic THA matched to 80 patients undergoing manual THA for osteoarthritis of the hip over one year. They found significantly

greater hip-specific functional outcomes in the robotic group when compared to the manual group which they attributed to improved component positioning from CT guidance. Despite these findings, no significant differences were demonstrated in patient satisfaction or subjective hip pain. The results of our study were not consistent with these previous findings which may be due to small sample size and differences in number of surgeons and combined experience performing each technique.

This study used a retrospective cohort design to compare study groups. Groups were numerically and demographically equal which was a strength of this study. An independent review of patient-reported outcome measures, including visual analog scale for pain and four objective measures (systolic blood pressure, diastolic blood pressure, heart rate, length of stay), were used to assess outcomes which allowed for multimodal comparison of surgical groups.

The sample size was not significantly different between surgical groups; however, the small quantity of patients in each surgical group was a limitation of this study. By excluding patients discharged on POD0 and any preoperative diagnosis that was not "osteoarthritis of the hip" or "degenerative joint disease of the hip," the sample size for analysis was significantly reduced. Patients discharged on POD0 tended to be younger with likely higher functional status compared to older patients discharged on POD1 or after. Although the data are not directly generalizable to patients discharged on POD0, the differences observed are a more conservative estimate. Inclusion of POD0 may have further increased the difference in manual versus robotic THA pain scores as patients discharged on POD0 likely had lower pain scores. Additionally, there was a greater proportion of patients that underwent manual THA compared to robotic THA (15 versus 2). Future studies may seek to include other indications for THA, including femoral neck fracture and avascular necrosis of the femoral head, to further delineate any potential differences in outcomes between surgical techniques.

This study was of retrospective design with multiple limiting factors due to inability to form a standardized protocol for technique selection (i.e. anterior, posterior), surgeon experience, and analgesia. However, by including multiple surgeons the data was more generalizable as compared to a single surgeon performing both techniques. Robotic THA is new technology that requires time and repetition to perform at the same quality as older technology, such as manual THA. MAKOplasty robotic technology has been utilized at this institution since the fall of 2015, whereas manual technology has been the standard since THA was first introduced in 1969. Therefore, surgeons performing the manual technique have had more time to perfect their craft. It is foreseeable that the robotic technique would improve in quality measures once more time has passed.

The sample size of 79 patients for analysis was increased by including patients who underwent the posterior approach. Although, comparison to the anterior approach differs in the anatomic structures dissected during surgery, which could potentially impact pain levels. Of the 6 major studies reviewed, only 3 fully disclosed the type of approach to the hip joint used in their studies. None analyzed differences in postoperative pain between surgical approaches. Perets et al.[7] had a sample size of 170 and included patients who underwent the anterior and posterior approach, approximately 44% underwent anterior approach and 57% underwent posterior approach. However, both approaches were utilized to make the data more generalizable. They did not discuss analysis of differences in pain between approaches. Clement et al.[2] had a sample size of 120 and utilized the posterior approach of the hip joint for all patients. Bargar and colleagues had a small sample size of 67 and utilized the posterolateral approach of the hip joint for all patients. Chen et al.[5] conducted a systematic review and meta-analysis of 8 studies with a total of 1512 patients. Five of the studies utilized a posterolateral approach, whereas the approach(es) used in the other 3 studies were not disclosed. Remily et al.[4] had a large sample size with 4630 patients allocated to the robotic and manual THA groups; however, they did not specify the approach(es) utilized. Karunaratne et al.[3] also had a large sample size of 1342 but did not disclose the approach(es) utilized.

Another limitation of this study was the lack of baseline preoperative pain scores within the facility's EMR. Therefore, differences in the degree of improvement in pain could not be adequately evaluated between groups. Future studies with a prospective design may seek to address the collection of preoperative baseline pain scores and extend the follow-up period for better evaluation of long-term outcomes.

5. Conclusion

Total hip arthroplasty performed via robotic technique demonstrated a statistically significant increase in postoperative pain outcomes when compared to manual technique. However, there may be a lack of clinically significant difference in

postoperative pain scores between groups. There were no differences regarding length of stay or change in vital signs between preoperative and postoperative periods between groups.

Conflict of interest

Brienne Paradis is a 3rd-year medical student from the University Of New England College Of Osteopathic Medicine (UNECOM) who is on clinical rotation at Berkshire Medical Center in Pittsfield MA. Andrea Bodine, MD is an American College of Obstetrics and Gynecology certified physician, Associate Clinical Professor at UNECOM, and research mentor. We do not have conflicts of interest or financial disclosures.

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