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Patients' Perception of Technology: an Update of Patients' Understanding of Robotics and Navigation in Total Joint Arthroplasty

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SUMMARY

Background. Given the increasing use of RN in orthopaedics, our aim is to evaluate TJA patients' understanding of RN technology.

Methods. A survey based cross sectional study was conducted in one joint replacement clinic from January- March 2021. Questions pertaining to demographic information, robotics and navigation prevalence, autonomy, benefits, drawbacks, costs, and patient experiences and attitudes were asked.

Results. Ninety-seven completed questionnaires were included in our results. 70.1% of patients knew that some orthopaedic surgeons use robotics and navigation systems in surgery. 71.1% had not undergone or did not know a first degree relative who had undergone an orthopaedic surgery performed with RN assistance. 86.6% of patients thought that >10% of operations were performed using a RN system. 58.7%, 49.4% and 49.4% of the patients believed that RN makes surgeries more accurate, easier, and quicker, respectively. 73.2% believed that robotic surgery would increase the price of their surgery. 46.3% answered that RN costs > $ 100,000. 55.7% of the patients responded that they would be willing to pay extra for a RN assisted surgery. 39.2% of patients were unsure of whether they would like to have RN surgery.

Conclusions. Patients' understanding of robotic and navigation in arthroplasty seems to be limited and inconsistent. With increased direct-to-consumer marketing of these technologies, it is critical for physicians and healthcare systems to promote balanced and complete information.

KEY WORDS

Arthroplasty; joint replacement; robotics; navigation; technology.

INTRODUCTION

Total Joint Arthroplasty (TJA) is amongst the most frequent and most successful orthopaedic surgeries performed (1) With increasing average age, prevalence of obesity and improved patient reported outcomes (PRO), the number of TJA is steadily increasing (1). Many studies have assessed patient satisfaction and understanding of total joint replacement (2-7). The literature demonstrates that patient expectations are a strong contributor to their overall satisfaction (8). Since the advent of robotic and navigation (RN) assisted surgery in orthopaedics, RN has demonstrated promising joint replacement outcomes (9, 10). RN are used to help with presurgical planning, aid in precision of cuts and mechanical axis alignment (9). The technology's use in arthroplasty is rising steadily and is becoming a target for healthcare marketing (11). With its increasing use and publicity, it is important to evaluate patients' understanding of RN and how its use impacts their expectations of surgical outcomes. Though

research is revealing the utility of the technology in arthroplasty, little is known about how much orthopaedic patients themselves currently understand about it (12). Given the increasing use of RN in our institutions and around the world, it is necessary to evaluate patients' understanding of these evolving technologies. We hypothesize that patients have a poor understanding of the cost and role of these systems, and that this may be impacted by patient age, education level, and race.

METHODS

Study protocol

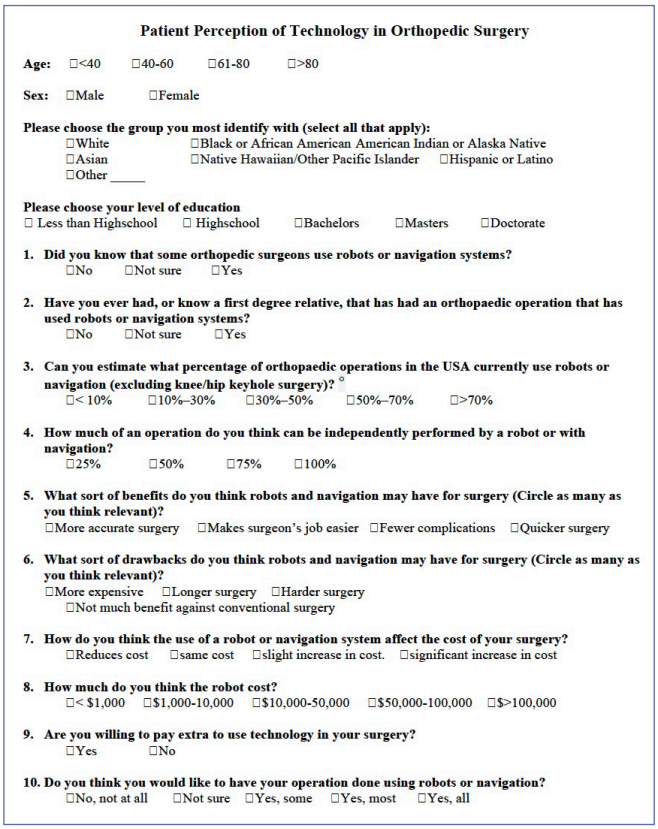
The current study was conducted in accordance with the Declaration of Helsinki and institutional ethical standards. Institutional Review Board Policy and Procedure Committee (IRB) approval was obtained from the University of Miami Hospital (20210388 - Date of approval: September 2020). The study is an observational cross-sectional study and was completed in accordance with STROBE guidelines. Data was prospectively collected through administration of a survey-based questionnaire. All collected information was deidentified. Patient consent for participation in the current study was obtained verbally prior to the administration of the questionnaire as required by our institutions IRB.

Setting and eligibility criteria

Survey based questionnaires were administered in one adult reconstruction clinic at the University of Miami Hospital between January and March 2021. Patients were included if they were over the age of 18, had the capacity to consent, and were interested in or had undergone an elective joint replacement surgery. Patients were excluded if they did not meet inclusion criteria. All incomplete surveys were excluded from the final results.

Questionnaire

97 paper-based questionnaires were distributed to the patients of one adult reconstruction clinic. The survey was reviewed and approved by our institution's IRB. Prior to an appointment with their joint replacement surgeon, research fellow SH approached patients to determine eligibility and willingness to partake in the current study. Verbal consent was acquired if inclusion criteria was met, and patients were given time to complete the survey independently. The survey administrator was available to answer questions and address concerns. Surveys were available in both English and Spanish. No identifying information was recorded. Questions regarding demographic information, robotics and navigation prevalence, autonomy, benefits, drawbacks, costs, and patient experiences and attitudes were included (**figure 1**). Participants had the option to include more than one race in their demographic responses.



Patient Perception of Technology in Orthopedic Surgery

Age: ☐<40 ☐40-60 ☐61-80 ☐>80

Sex: ☐Male ☐Female

Please choose the group you most identify with (select all that apply):
☐White ☐Black or African American ☐American Indian or Alaska Native
☐Asian ☐Native Hawaiian/Other Pacific Islander ☐Hispanic or Latino
☐Other _____

Please choose your level of education
☐ Less than Highschool ☐ Highschool ☐Bachelors ☐Masters ☐Doctorate

1. **Did you know that some orthopedic surgeons use robots or navigation systems?**
☐No ☐Not sure ☐Yes
2. **Have you ever had, or know a first degree relative, that has had an orthopaedic operation that has used robots or navigation systems?**
☐No ☐Not sure ☐Yes
3. **Can you estimate what percentage of orthopaedic operations in the USA currently use robots or navigation (excluding knee/hip keyhole surgery)?**
☐< 10% ☐10%–30% ☐30%–50% ☐50%–70% ☐>70%
4. **How much of an operation do you think can be independently performed by a robot or with navigation?**
☐25% ☐50% ☐75% ☐100%
5. **What sort of benefits do you think robots and navigation may have for surgery (Circle as many as you think relevant)?**
☐More accurate surgery ☐Makes surgeon's job easier ☐Fewer complications ☐Quicker surgery
6. **What sort of drawbacks do you think robots and navigation may have for surgery (Circle as many as you think relevant)?**
☐More expensive ☐Longer surgery ☐Harder surgery
☐Not much benefit against conventional surgery
7. **How do you think the use of a robot or navigation system affect the cost of your surgery?**
☐Reduces cost ☐same cost ☐slight increase in cost. ☐significant increase in cost
8. **How much do you think the robot cost?**
☐< $1,000 ☐$1,000-10,000 ☐$10,000-50,000 ☐$50,000-100,000 ☐$>100,000
9. **Are you willing to pay extra to use technology in your surgery?**
☐Yes ☐No
10. **Do you think you would like to have your operation done using robots or navigation?**
☐No, not at all ☐Not sure ☐Yes, some ☐Yes, most ☐Yes, all

Figure 1. Questionnaire on Robotics and Navigation in Orthopedic Surgery.

Outcomes of interest

Our aim was to obtain roughly 100 survey responses from adult reconstruction patients with the goal of assessing patients' understanding of robotics and navigation technology. Secondarily, we sought to analyze how patient demographics, including age, sex, race, and education level impacted their answer choices.

Statistical analysis

Surveys were assessed for completeness. All completed responses were tabulated in Microsoft Excel 2021. Statistical analysis was conducted using SPSS (Version 27.0.1.0, 2020) by author SH at the University of Miami Hospital, Florida, USA. A Pearson's chi-squared analysis and Fisher's exact test were used to assess association between demographic sex, gender, race, and education and answer choices.

All data was assessed as categorical data. Multiple response questions 5 and 6 were broken down into yes/no responses for each answer choices and assessed categorically. Race was assessed categorically as yes/no for choices: White, Asian, Black, Hispanic, and Other. A P-value of 0.05 was used as a cut of for statistical significance.

RESULTS

Cohort

100 surveys were administered from January-March 2021. Three surveys were excluded due to incomplete responses, leaving 97 surveys included in our final analysis.

Patient demographics

The median age of respondents was between 61-80 years old (range < 40 - > 80). Fifty-four patients were female (55.7%). Patients' racial identifications included 51 White, 2 Asian, 23 Black, 0 Native Islander, 0 Native American, 29 Hispanic, and 2 others. Eight of the patients responded as bi-racial or multi-racial. Patients' highest education level included 1 less than high school, 41 completed high school, 30 completed a bachelors, 15 completed a masters, and 10 completed a PhD (**table I**).

Responses

Most patients (70.1%) knew that some orthopaedic surgeons use robotics and navigation systems in surgery (**figure 2**). Most (71.1%) had not undergone or did not know a first degree relative who had undergone an orthopaedic surgery performed with RN assistance (**figure 3**). 86.6% of patients thought that > 10% of operations were performed using a RN system; 4.1% indicating > 70% and 13.4% indicating < 10% (**figure 4**). 29.9%, 33.0%, 29.9%, 7.2% of patients believed that 25%, 50%, 75%, 100% of an operation could be independently performed by using RN, respectively. 58.7%, 49.4% and 49.4% of the patients believed that RN makes surgeries more accurate, easier, and quicker, respectively. A majority, 67.0%, believed RN makes arthroplasty more costly as a whole (**figure 5**) and 73.2% believed that robotic surgery would increase the price of their surgery; conversely, 26.8% believed that robotics would not change or reduce the price of their surgery (**figure 6**). 46.3% answered that RN costs > $ 100,000 (**figure 7**). 55.7% of the patients responded that they would be willing to pay extra for a RN assisted surgery. 39.2% of patients were unsure of whether they would like to have RN surgery, 13.4% did not want involvement of RN in their surgery, 9.3% wanted all of

Table I. Socio-demographic characteristics of the participants.

Characteristic	Frequency (n)	Percentage (%)
Total	97	100%
Gender		
Male	43	44.3%
Female	54	55.7%
Race		
White	51	52.5%
Asian	2	2.1%
Black	23	23.7%
Native Islander	0	0%
Native American	0	0%
Hispanic	29	29.9%
Other	2	2.1%
Bi- or Multi- Racial	8	8.2%
Education		
< High School	1	1.0%
High School	41	42.3%
Bachelors	30	30.9%
Masters	15	15.5%
PhD	10	9.7%

the surgery performed by RN, and 27.8% wanted some or most of the surgery to be performed with RN (**figure 8**).

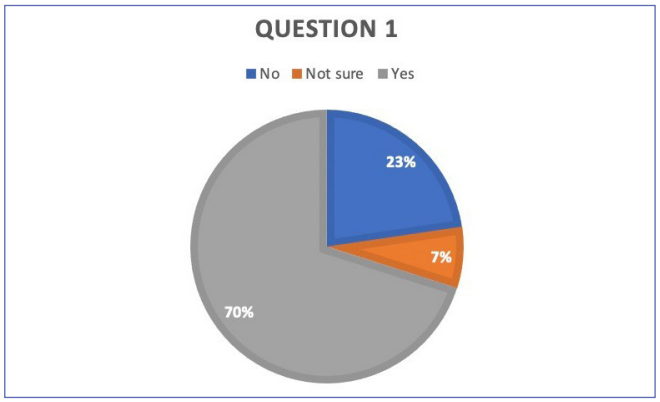


Figure 2. Pie Chart of Question 1 Responses.

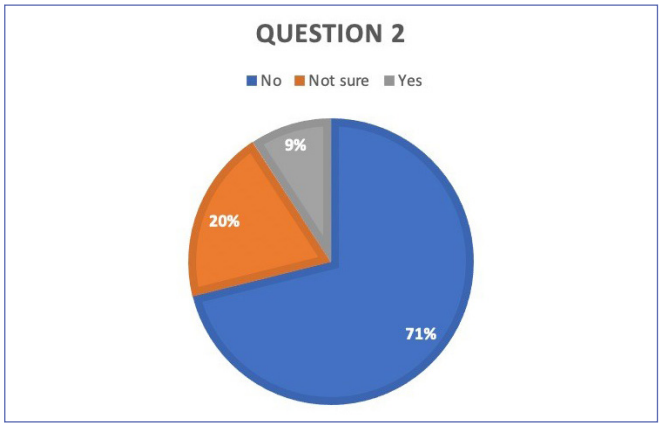


Figure 3. Pie Chart of Question 2 Responses.

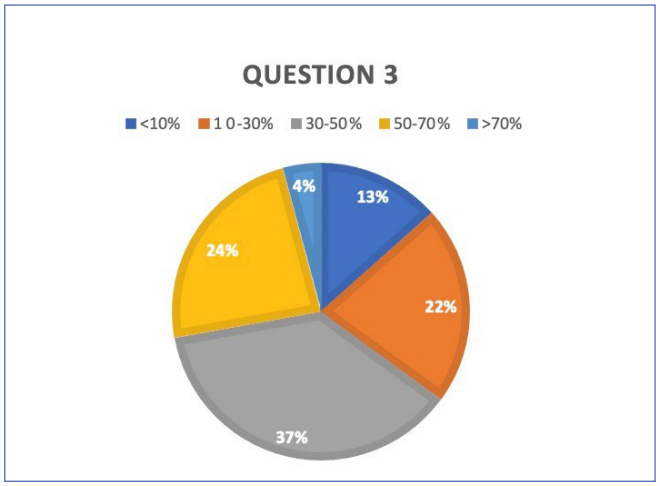


Figure 4. Pie Chart of Question 3 Responses.

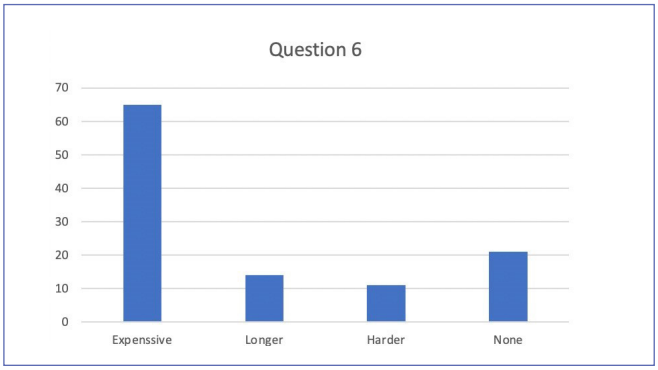


Figure 5. Bar Chart of Question 6 Responses.

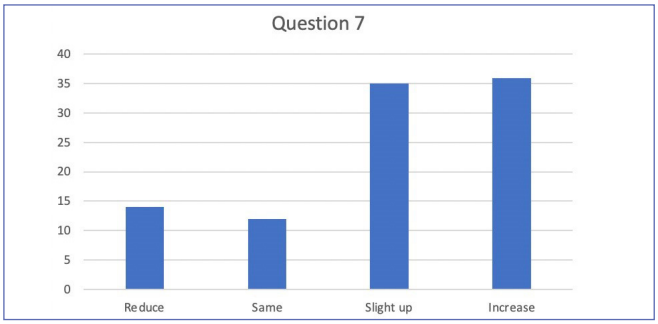


Figure 6. Bar Chart of Question 7 Responses.

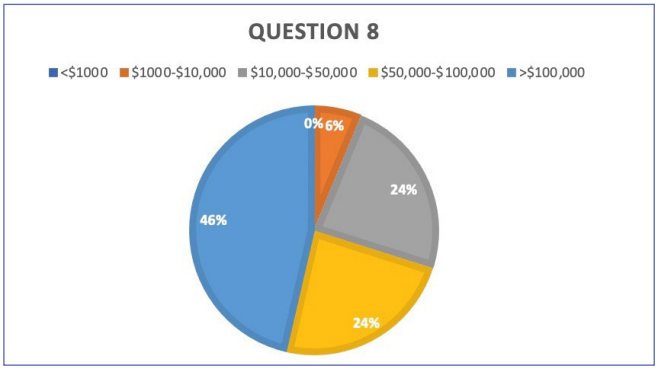


Figure 7. Pie Chart of Question 8 Responses.

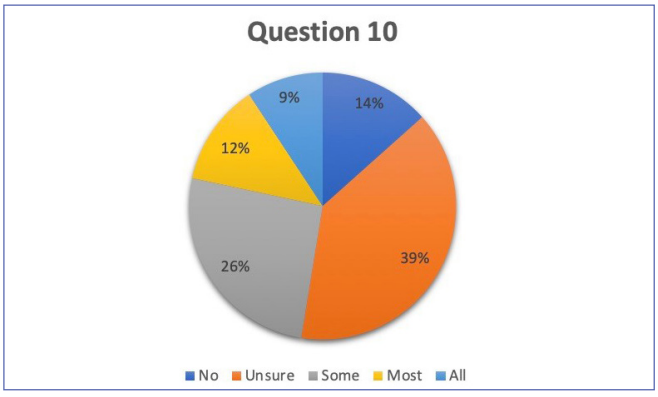


Figure 8. Pie Chart of Question 10 Responses.

Demographic impact on response choice

Age and sex were independently associated with all answer choices. Education was associated with answer choice for question 2 and 5a. Education was therefore associated with respondents undergoing RN surgery or knowledge of a first degree relative who has had RN assisted orthopaedic surgery ($p = 0.029$). Education was also associated with whether respondents believed RN assisted surgery made surgery more accurate or not ($p = 0.048$). Several racial demographics had associations with answer choices. White race was associated with questions 1, 9, 10. Therefore, Whites had an association with whether they knew some orthopaedic surgeons use RN assisted surgery or not ($p = 0.004$); they had an association with whether they would pay extra for robotic surgery or not ($p = 0.008$) and there was also an association with choice of level of RN involvement in their surgery ($p = 0.014$). Black race was associated with answer choices for questions 5a and 10. Therefore Blacks choice of whether RN was more accurate or not was not independent of race ($p = 0.007$); there was also an association with their choice of level of RN involvement in surgery ($p = 0.026$). Hispanic race was associated with questions 1 and 2. Therefore Hispanics choice of whether they knew that some orthopaedic surgeons use RN was not independent of their race ($p = 0.033$). Hispanics also had an association with whether they had or knew a first degree relative that has had an RN assisted orthopaedic surgery or not ($p = 0.032$).

DISCUSSION

Given the rise of RN in orthopaedics, our study adds to the literature by serving as an evaluation of patients understanding of the new technology. Our results demonstrate that most patients know of RN assisted surgery in orthopaedics, though there seems to be no consistent understanding of details on the subject. A majority either did not know, or were unsure if they knew, someone who had an orthopaedic robotic surgery in the past, though most believed RN surgery comprised > 10 % (median of 30-50%) of surgeries. Perceived level of autonomy and impact of the technology on surgical costs was likewise diverse amongst patients. Over 50% incorrectly believed RN systems cost < $ 100,000. Likewise, greater than 50% of patients were willing to pay extra for RN assisted surgery though 39.1% were unsure whether they would like a robotic surgery at all. When stratifying our results by age, gender, race, and education we found associations between education and race and several answer choices (**table II** and **table III**).

A similar study was conducted by Jassim Benjamin-Laing *et al.*'s 2014 study from the United Kingdom (12). Our total cohorts were comparable in size and results. Comparably, 9% of our cohort and 12% of theirs had or knew someone who had undergone a robotic surgery; 37% of our cohort believed that most or all (75% or 100%) of an operation could be performed by a RN system, similar to their cohort (33%). 87% of our cohort compared to 75% of their cohort believed > 10% of orthopaedic surgeries were performed using RN. Similarly, roughly 50% of both cohorts believed that RN made surgery more accurate, easier, or quicker compared to manual TJA. Roughly 70% of both cohorts also correctly believed RN to be more expensive than conventional surgery, and roughly 20% of both believed RN had no benefit compared to conventional surgery. Around 50% of both cohorts would have at least some involvements of RN in their surgery. 13% of ours compared to 20% of their cohort would like no involvement of RN in their TJA.

Abundant marketing campaigns for RN surgeries exist with advertising typically suggesting personalized, faster, less painful, and easier surgeries (13). Our cohorts' responses on benefits and drawbacks of RN surgery largely agreed with these claims. In studies on RN in TKA, THA and UKA, robotics have in fact largely demonstrated superior precision in metrics such as implant positioning, offset, leg length and mechanical access alignment (14). Most of the evidence for improved clinical outcomes, however, is supportive of UKA to a greater degree than THA or TKA. Studies assessing UKA specifically, demonstrate improved implant survivorship, reduced pain, function scores and time to discharge compared to conventional surgery (15, 16). Conversely, RN in THA and TKA has demonstrated some benefit in pain and functional outcomes, though systematic reviews and meta-analysis have yet to demonstrate superiority compared to conventional surgery (14, 17). Established drawback of RN include, increased surgical time, learning curve and increased costs (14). Time has been shown to increase up to 25 minutes per surgery adding up to $ 1625 (14). At baseline value RN systems cost $ 800,000 though many are closer to $ 1,000,000 and can add several thousand dollars to patient cost (14). The most agreed upon drawback in our cohort was expense, to which 54 patients responded that they would be willing to pay more for robotic surgery. It is unlikely that RN companies include the drawbacks and lack of documented superiority to patients, possibly contributing to this majority. A 2012 study investigating direct-to-consumer internet advertising in robotic prostatectomy found unbalanced and misleading information (18). They therefore suggested government and medical societies increase their efforts in promotion of balanced education to patients (18). A similar study from 2007 demonstrated that over 52% of orthopaedic patients experienced some sort of direct-to-consumer advertising, which was correlated with higher requests for specific surgery or implant type (19). This becoming increas-

Table II. Questions associated with education stratified.

Question 2 (p = .029)		**No**	**Unsure**	**Yes**
	< HS	100% (1/1)		
	HS	68.3% (28/41)	31.7% (13/41)	
	BA	66.7% (20/30)	10% (3/30)	23.3% (7/30)
	MS	86.7% (13/15)	20% (2/10)	10% (1/10)
	PhD	70% (7/10)	20% (2/10)	10% (1/10)
Question 5a (p = .048)		**Accurate**		
	< HS	0% (0/1)		
	HS	51.2% (21/41)		
	BA	60.0% (18/30)		
	MS	53.3% (8/15)		
	PhD	100% (10/10)		

Table III. Questions associated with race stratified.

White Question 1 (p = 0.004)	**No**	**Unsure**	**Yes**		
	17.6% (9/51)	0% (0/51)	72.5% (37/51)		
White Question 9 (p = 0.007)	**Yes**	**No**			
	68.6% (35/51)	31.4% (16/51)			
White Question 10 (p = 0.014)	**No**	**Unsure**	**Some**	**Most**	**All**
	5.9% (3/51)	31.4% (16/51)	35.3% (18/51)	13.7% (7/51)	13.7% (7/51)
Black Question 5a (p = .007)	**Accurate**				
	34.8% (8/23)				
Black Question 10 (p = .026)	**No**	**Unsure**	**Some**	**Most**	**All**
	26.1% (6/23)	52.2% (12/23)	4.3% (1/23)	13.0% (3/23)	4.3% (1/23)
Hispanic Question 1 (p = 0.033)	**No**	**Unsure**	**Yes**		
	37.9% (11/29)	10.3% (3/29)	51.7% (15/29)		
Hispanic Question 2 (p = 0.032)	**No**	**Unsure**	**Yes**		
	89.7% (26/29)	6.9% (2/29)	3.4% (1/29)		

ingly relevant as the spread of fragmented and misinformation only continues to grow with the ubiquity of handheld smartphones and increased access to social media application.

Patients are left with decisions on how they would like their arthroplasty completed, though it appears many have fragmented knowledge on the subject. Though many options exist, RN is not as ubiquitous as patients might perceive. In our cohort, for example, most patients knew RN was performed by some orthopaedic surgeons, though a greater majority did not know or were unsure of someone who was operated with RN assistance. Two recently published studies on trends of robotic surgery indicated that surgeries performed using this relatively new technology number less than 10%. Using the National Inpatient Sample Database, Antonios and Korber *et al*. demonstrated that RA surgeries in TKA grew from 0.1% to 0.8% of all from 2009-2013 and that computer navigation use grew from 1.2% to 6.3% (11). Similarly, Boylan and Suchman *et al.* used the Statewide Planning and Research Cooperative System and demonstrated that technology assistance was used in 5.1% of all total hip, knee or UKA surgeries between 2008-2015 with a steady increase each year (20). RN was also more likely to be used in knee *versus* hip arthroplasty, high volume *versus* low volume hospitals, and on private insurance patients *versus* Medicaid and Medicare patients (20). This data represented metrics of 5 or more years ago and based on our search through online journals like PubMed and readily accessible search engines like Google, no recent data from reputable sources exists. Perhaps the lack of accessible information contributes to some degree of our patients markedly incorrect assessment of RN prevalence (most believing RN is involved in > 30% of surgeries).

Robot autonomy categories include passive, semi-autonomous (haptic), and autonomous. Passive indicates the machine completes a portion of the surgery under directs control of the surgeon; semi-autonomous require surgeon feedback to complete a task; autonomous can complete tasks independently of surgeon feedback. Earlier autonomous systems such as CASPER and ROBODOC showed potential in improving implant alignment and patient satisfaction though they also were found to have higher complication rate, surgical time and aborted surgeries (21). Passive systems like the Acrobat have demonstrated some utility in positioning TKA prosthesis, but under full control of the surgeon (10). More commonly used haptic systems, such as the Mako, couple preoperative planning with intraoperative adjustments. Mako has growing evidence of effectiveness in reducing intraoperative complications, improving patient activity and satisfaction scores, and placing implants with greater precision than manual total joint arthroplasty (22). The variety of RN systems available may have led to our cohort's variable estimates of independence.

Our study is not without limitation. Firstly, we administered our survey to one clinic's patients. Therefore, our results are not likely generalizable to the entire country but may reflect patients of the central Miami and surrounding areas. Our cohort did however include a group of patients diverse in age, education level, and race. Additionally, our sample size was relatively small, consisting of 97 patients. Our study was also not extensively piloted prior to administration, though a similar study has been conducted on 98 patients in the UK (12). The survey was also only conducted once per patient. Therefore, we were unable to assess if exposure to educational material would improve participants' understanding of the technology. Lastly, robotics and navigation were included as one entity in all questions, so to not confuse patients.

Further studies should investigate patients' understanding of RN in orthopaedics using a larger cohort, across multiple institutions. Researchers should also aim to assess the effect of unbiased educational material on participants' understanding of robotics and navigation. Furthermore, there is a need for more updated studies on the trends in utilization and prevalence of robotics and navigation in joint replacement.

CONCLUSIONS

Patients understanding of robotic and navigation in arthroplasty seems to be limited and inconsistent. Our cohort responded similarly to Jassim and Benjamin-Laing *et al*'s cohort from 2011, despite a decade time gap (12). Racial and education level's influence on answer choices were present. With increased direct-to-consumer marketing of these technologies, it is critical for patient satisfaction met their expectations, physicians and healthcare systems needs to promote balanced and complete information as part of patient's education.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

All authors contributed equally to this work.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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