

Research Article

Patient Perceptions of Emerging Technologies in Shoulder Surgery

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Introduction

Intraoperative navigation (NAV), augmented reality (AR), and robotics have emerged as promising new technologies in shoulder arthroplasty. Previous research in these areas has focused on the use of these technologies by surgeons, but not on understanding patient knowledge and perceptions. This study aimed to characterize patients' baseline understanding and perceptions of new technology in shoulder arthroplasty and see if educational content in this area enhances or changes their views of these technologies.

Methods

A 38-question survey was administered to adult patients to assess baseline knowledge and perception of NAV, AR, and robotic surgery technologies. Subjects were recruited from local public areas (e.g., golf clubs, and grocery stores) and orthopedic clinics across Palm Beach County to provide a broad array of demographics. Baseline assessments were performed, and then educational materials were provided about each of the technologies. After learning about the different technologies, the participants repeated the survey. Bivariate analysis of categorical variables was performed. Multivariable logistic regression model evaluated factors associated with a preference for the use of technology in shoulder procedures.

Results

Of the 77 responders, the majority were not familiar with NAV (57.1%) or AR (70.1%). Patients were somewhat familiar with robotics (51.9%). NAV and robotic surgery were perceived to lead to better results in 51.9% and 53.2% of responders, respectively. AR was perceived to have no specific benefit (51.9%) after shoulder surgery. After reading the provided educational materials, most patients expected faster recovery (57.1%) and fewer complications (53.2%) with NAV. In contrast, with AR and robotics, most patients (>50%) expected no specific benefits. Most respondents did not see these technologies would be helpful for pain relief. The primary reported concerns of respondents were lack of surgeon experience with the technology and increased cost. Overall, 50% of participants had a preference for surgeons who use these technologies, and most (68.8%) thought surgeons using these technologies are of similar skill compared to surgeons who do not utilize technology. Multivariate regression modeling revealed that respondents of Asian race were more likely to prefer surgeons who do not use technology ($p = 0.042$).

Conclusion

The public appears to be unaware of various forms of technology used today in shoulder surgery and there are misperceptions of superior outcomes with these technology-assisted surgeries. Brief descriptions of these technologies did appropriately enhance patients' understanding and expectation for these technologies applied in shoulder surgery. More patient-directed education is needed if we are to incorporate these innovative technologies in surgery. Furthermore, this may prove to be a powerful marketing tool for surgeons and hospitals.

INTRODUCTION

In shoulder surgery, technology is commonly used in total anatomic (TAA) and reverse shoulder arthroplasties (RSA). When performing these procedures, ideal long-term results are achieved by accurately restoring the glenoid version and ensuring proper implant stability with adequate soft tissue tension. However, anatomic variations of the scapula and humerus due to osteoarthritis or fractures can hinder a surgeon's ability to restore these components (Porcellini et al. 2019). Furthermore, pathological glenoid inclination and retroversion greater than 15° can cause poor joint biomechanics leading to uneven stress and a higher risk of prosthetic loosening and subsequent failure (Mansat et al. 1998; Walch et al. 1999). Due to the complex and unique anatomy of each patient, standard two-dimensional imaging is often

inadequate for preoperative planning. Instead, computed tomography (CT) scans, magnetic resonance imaging (MRI), and fluoroscopy can be used in conjunction with intraoperative technology to guide the surgeon. Common technologies used by orthopedic surgeons include intraoperative navigation (NAV), augmented reality (AR), and robotics.

NAV utilizes pre-operative imaging to assist surgeons in identifying the ideal anatomic location to cut through tissue (Karkenny et al. 2019). CT scans and fluoroscopy are commonly used in conjunction with a navigation software to identify key landmarks specific to the patient's unique anatomy (Karkenny et al. 2019). Moreover, NAV and robotics can be utilized together, such as in knee arthroplasty where the combination of the two technologies allows the surgeon to remove bone with precision and optimize com-

ponent angularity to improve patient outcomes and prosthetic biomechanics (Karkenny et al. 2019). Additionally, in RSA, NAV has been shown to improve the accuracy in placement of the glenoid implant, thus decreasing the risk of complications (Levy et al. 2014). Despite its benefits, NAV has been shown to lengthen operating times, which may discourage some surgeons from utilizing this technology (Kircher et al. 2009).

AR is the use of a computer-generated image that can be viewed while simultaneously viewing the real world (Verhey et al. 2020). In the operating room, preoperative CT or MRI scans are used to present the patient's anatomy as an overlay to the operative area (Verhey et al. 2020). AR has already shown to be beneficial in numerous orthopedic procedures such as fracture fixation. Furthermore, it is currently being evaluated for its use in joint arthroplasty (Verhey et al. 2020). Some studies have shown that the use of AR in hip arthroplasty enhances the placement of prosthetic components (Casari et al. 2021; Verhey et al. 2020). Additionally, AR has been utilized in spine surgery to improve the accuracy of pedicle screw placement (Ghaednia et al. 2021).

Robotics is the use of an automatic device that can be programmed to perform various tasks (Jacofsky and Allen 2016; Innocenti and Bori 2021). While this a relatively new concept in shoulder arthroplasty, it shows promise in recent studies (Twomey-Kozak et al. 2023; Han et al. 2023; Lim and Chun 2023). In joint arthroplasty, the advantage of utilizing robotics is that it allows surgeons to recreate the patient's anatomical alignment (Jacofsky and Allen 2016). Specifically in shoulder arthroplasty, robotics improved the accuracy of implant component placement and angulation (Jacofsky and Allen 2016; Darwood et al. 2022). The improved alignment has been shown to decrease risk of complications and the need for revision arthroplasty (Jacofsky and Allen 2016).

While much of the literature discusses the benefits of technology-assisted orthopedic surgery from the perspective of improved outcomes and increased accuracy, there is a paucity regarding patient perceptions of these technologies. One study reviewed patient satisfaction after undergoing robot-assisted surgeries by multiple surgical specialties and found that patients had overall positive experiences (Moloney et al. 2020). Pagani et al. performed a study to assess the patient perceptions specifically of robotics in orthopedic surgery (Pagani et al. 2021). Their study found that the majority of respondents believed that robot-assisted surgery leads to better outcomes, less complications, and less pain than traditional surgery. The present study aims to expand upon the findings of Pagani et al. to assess patient perceptions on the use of technology specifically in shoulder surgery. This study also evaluates how patient education impacts these perceptions. We hypothesize that patients will have positive perceptions of these technologies and will support their use in orthopedic procedures.

METHODS

A 38-question survey was administered to adult patients to assess demographics and baseline knowledge and perception of NAV, AR, and robotic surgery technologies (**Appendix**). Demographic information included age, gender, race, and level of education. Subjects were recruited from local public areas (e.g., golf clubs, and grocery stores) and orthopedic clinics across Palm Beach County. All participants were at least 18 years of age, and no incentives were provided to participants.

Following completion of the survey, the subjects received educational materials about each of the technologies. Afterwards, the survey was readministered.

STATISTICAL ANALYSIS

Pearson's chi-square and Fisher's exact test were employed to perform bivariate analysis of categorical variables. Additionally, a multivariate ordinal logistic regression model was constructed to investigate factors associated with a preference for surgeon use of NAV, AR, or robotic technology during orthopedic procedures. All statistical analyses were performed using R (Version 4.3.2; R Foundation for Statistical Computing, Vienna, Austria). A p-value of <0.05 was considered statistically significant.

This study was approved by an Institutional Review Board (IRB).

RESULTS

DEMOGRAPHICS

In total, 91 participants completed the survey. After exclusion of duplicates and incomplete surveys, 77 responses were included for analysis. The average age was 35.9, and 40.2% were male, and 59.7% were female. The sample was 32.4% African American, 31.2% Caucasian, 24.7% Hispanic, and 11.7% identified as other. Additionally, 81.9% of the population had at least a bachelor's degree. Of the respondents, 92.2% never had shoulder surgery. When asked about their technology use, 49.4% of those surveyed said they currently use new technologies when other people start to use them (**Table 1**).

INTRAOPERATIVE NAVIGATION (NAV)

Prior to reading the educational material on NAV, 57.1% of respondents answered that they were not familiar with the use of computer-navigated technologies in orthopedic surgeries, and 54.5% said they do not have a preference if their surgeon used NAV technology. Furthermore, 51.9% of those surveyed believed that the use of NAV leads to better outcomes when used in shoulder surgery. The most frequent concern respondents reported regarding NAV was the lack of surgeon experience (33.8%).

After reading about NAV, 37.7% of respondents indicated a preference for their surgeon to use this technology intraoperatively, while 42.9% had no preference. Furthermore,

Table 1. Patient Demographics

Survey Questions	Responses
Age	35.9
Sex	
Male	31 (40.3%)
Female	46 (59.7%)
Race	
White	24 (31.2%)
Black	25 (32.5%)
Hispanic	19 (24.7%)
Asian	5 (6.5%)
Other	4 (5.1%)
Education Level	
Some High School	3 (3.9%)
High School Degree	9 (11.7%)
Bachelor's Degree	36 (46.8%)
Master's Degree	19 (24.7%)
PhD or Higher	8 (10.4%)
Trade School	2 (2.5%)
Previous Surgery	
Yes	6 (7.8%)
No	71 (92.2%)
When it comes to technology, what best describes you?	
I am skeptical of new technologies and use them only when I have to	5 (6.5%)
I am usually one of the last people I know to use new technologies	3 (3.9%)
I usually use new technologies when most people I know do	38 (49.4%)
I like new technologies and use them before most people I know	23 (29.9%)
I love new technologies and am among the first to experiment with and use them	8 (10.4%)

48.1% believed that NAV leads to better results, and 49.4% reported that the results were comparable to surgeries that did not utilize technology. The most common concern, expressed by 37.7% of respondents, was the lack of surgeon experience with the technology.

In terms of outcomes, 53.2% of respondents believed that using NAV leads to fewer complications both during and after orthopedic surgeries. Regarding pain levels, 53.2% of respondents believed that NAV results in pain levels similar to surgeries that do not use the technology, with only 3.9% believing it leads to increased pain. Additionally, 57.1% of respondents believed that NAV usage contributes to faster recovery times ([Table 2](#)).

AUGMENTED REALITY (AR)

Before reading about AR technology, 70.1% of patients indicated that they were not familiar with its use in orthopedic surgery. Additionally, 79.2% expressed no preference regarding whether their surgeon should use AR for orthopedic procedures. Furthermore, 45.5% of respondents believed that AR improves outcomes. The primary concern

patients have about AR (45.5%) is the perceived lack of experience among surgeons in using this technology.

After reading the description of AR technologies, 33.8% of respondents said they would prefer their surgeon to use AR, and 39% said that they believed AR leads to better outcomes. The greatest concern with the use of AR was the lack of surgeon experience with the technology (53.2%). Furthermore, 35.1% believed that AR usage leads to fewer complications both during and after orthopedic surgeries. Moreover, 62.3% believed the use of AR leads to postoperative pain levels that are comparable to surgeries that did not utilize the technology. Only 3.9% believed that AR increases pain levels. Lastly, 29.9% of respondents believed that AR usage results in faster recovery times ([Table 3](#)).

ROBOTICS

Before reading about robotics in orthopedics, 51.9% of respondents stated they were somewhat familiar with robotic technology. Additionally, 58.4% expressed no preference regarding whether their surgeon should use robotic technology. Furthermore, 53.2% of respondents believe that using robotics leads to improved outcomes. The most com-

Table 2. Intraoperative Navigation

Survey Questions	Responses
<i>Before reading description of technologies</i>	
Are you familiar with the use of computer-navigated surgery technology in orthopedic surgery?	
Very Familiar	4 (5.2%)
Somewhat Familiar	29 (37.7%)
Not at all	44 (57.1%)
If you were to have shoulder orthopedic surgery, would you prefer the use of computer-navigated surgery technology?	
Prefer computer-assisted technology	29 (37.7%)
No Preference	42 (54.5%)
Prefer non-computer-assisted surgery	6 (7.8%)
Do you think that the use of intraoperative navigation technology leads to better results following shoulder orthopedic surgery in general?	
Better Results	40 (51.9%)
Equal Results	36 (46.8%)
Worse Results	1 (1.3%)
What would be your major concern regarding intraoperative navigation shoulder surgery?	
Increased Cost	17 (22.1%)
Operation takes longer	2 (2.6%)
Lack of surgeon experience with technology	26 (33.8%)
Lack of research to support the use of the technology	17 (22.1%)
I am not concerned	15 (19.5%)
<i>After Reading Description of Technologies</i>	
If you were to have shoulder orthopedic surgery, would you prefer the use of intraoperative navigation technology?	
Prefer intraoperative navigation technology	29 (37.7%)
No preference	33 (42.9%)
Prefer non-intraoperative navigation surgery	5 (6.5%)
I still don't know what intraoperative navigation technology is	10 (12.9%)
Do you think that the use of intraoperative navigation leads to better results following shoulder orthopedic surgery in general?	
Better Results	37 (48.1%)
Equal Results	38 (49.3%)
Worse Results	2 (2.6%)
What would be your major concern regarding intraoperative navigation technology in shoulder surgery?	
Increased cost	16 (20.8%)
Operation takes longer	2 (2.6%)
Lack of surgeon experience with computer-assisted surgery	29 (37.6%)
Lack of research to support the use of computer-assisted surgery	18 (23.4%)
I am not concerned	12 (15.6%)
Do you think that the use of intraoperative navigation technology leads to fewer complications during or after orthopedic surgery?	
Fewer complications	41 (53.2%)
Equal complications	34 (44.2%)
More complications	2 (2.6%)
Do you think that the use of intraoperative navigation technology leads to less pain with orthopedic surgery?	
Less pain	33 (42.9%)

Equal pain	41 (53.2%)
More pain	3 (3.9%)
Do you think that the use if intraoperative navigation technology leads to faster recovery after orthopedic surgery?	
Faster	44 (57.1%)
Equal	31 (40.3%)
Slower	2 (2.6%)

mon concern among participants before reading about robotics, accounting for 29.9% of responses, is the potential malfunction of the robot leading to patient harm.

After reading about robotics, 27.3% of respondents expressed a preference for their surgeon to use this technology, while 46.8% had no preference. Additionally, 45.5% of respondents believed that using robotics leads to improved outcomes. In contrast to the survey completed prior to reading the educational materials, the most common concern among respondents (29.9%) was the perceived lack of surgeon experience in using robotics technology. Furthermore, 35.1% of respondents believed that using robotics results in fewer complications both during and after orthopedic surgeries. Regarding pain, 59.7% of respondents believed that using robotics results in pain levels similar to surgeries that do not use the technology, with only 3.9% believing it leads to increased pain. Additionally, 36.4% of respondents believe that using robotics leads to faster recovery times ([Table 4](#)).

TECHNOLOGY OVERVIEW

Before reading about the various technologies, 24.7% of respondents believed that surgeons who use these technologies are better than those who do not. After reading the descriptions, this belief increased to 28.6% ([Table 5](#)).

A bivariate analysis using a chi-square test was conducted to determine if there was an association between gender, race, or education and a preference for technology. The results showed that gender ($p = 0.86$), race ($p = 0.33$), and education ($p = 0.5$) did not have a significant relationship with a preference for using technology in orthopedic shoulder procedures.

Further analysis through multivariable regression modeling revealed that individuals of Asian race (OR 0.049, 95% CI 0.003-0.867, $p = 0.04$) were significantly less likely to prefer the use of technology during orthopedic procedures. Other demographic factors such as race, education level, age, and gender did not exhibit a significant preference ([Table 6](#)).

DISCUSSION

Existing literature has established the benefits of technology like NAV, AR, and robotics in orthopedic surgery, leading to improved patient outcomes and enhanced training for future surgeons (Porcellini et al. 2019; Goh et al. 2021; Mao et al. 2021). However, patients' baseline understanding

and perceptions of new technology in shoulder arthroplasty is unclear. This study aimed to bridge this gap in literature and see if educational content enhances or changes their views of these technologies. This study provides novel information because it prospectively evaluates perceptions of orthopedic technology from participants who have not directly experienced these surgical techniques.

It is well documented that technology can improve post-operative outcomes in shoulder arthroplasties (Porcellini et al. 2019b). Despite this, only 51.9% thought NAV improved outcomes, 45.5% thought AR improved outcomes, and 53.2% thought robotics improved outcomes. Notably, these values dropped to 48.1%, 39.0%, and 45.5%, respectively, after reviewing the educational materials. Many also believe that technology usage leads to comparable or better outcomes, fewer complications, less pain, and view surgeons who utilize technology as comparable or superior to those who do not. Moreover, most indicated that they would either have no preference or would prefer their surgeon to use the technologies. Similarly, Pagani et al. found that, while most respondents believed that robotics enhances surgical outcome, only 34% preferred robotic-assisted surgeries over the manual approach. Even when accounting for surgeon volumes, 49% preferred a low-volume surgeon using robotics to a high-volume surgeon using the conventional approach (Pagani et al. 2021). These results suggest a discrepancy between public perception and the current orthopedic literature.

The most common concern expressed by respondents was a lack of surgeon experience with these technologies. Orthopedic surgeons can address this by highlighting their experience and training in an effort to reassure their patients. Another concern related specifically to robotics was the potential for malfunction leading to patient harm. However, the percentage of participants that cited this as their primary concern decreased after reading the description of robotics. This indicates that patient education could mitigate this worry. The data also identified Asian race as an independent predictor for a preference against surgeons using intraoperative technology. However, all other races, patient gender, and education level did not display a significant preference or aversion towards surgeons who utilize technology.

Additionally, previous studies have examined patient perceptions regarding the use of robotics in both general and orthopedic surgeries. Ahmad et al. reported that most patients believed robotic-assisted laparoscopic surgery had lower complication rates, blood loss, hospital stays, and in-

Table 3. Augmented Reality

Survey Questions	Responses
<i>Before reading description of technologies</i>	
Are you familiar with the use of augmented reality technology in orthopedic surgery?	
Very familiar	2 (2.6%)
Somewhat familiar	21 (27.3%)
Not at all	54 (70.1%)
If you were to have shoulder orthopedic surgery, would you prefer the use of augmented reality technology?	
Prefer augmented reality	9 (11.7%)
No preference	61 (79.2%)
Prefer no augmented reality use in my surgery	7 (9.1%)
Do you think that the use of augmented reality technology leads to better results following shoulder orthopedic surgery in general?	
Better Results	35 (45.5%)
Equal Results	40 (51.9%)
Worse Results	2 (2.6%)
What would be your major concern regarding augmented reality shoulder surgery?	
Increased cost	11 (14.3%)
Operation takes longer	1 (1.3%)
Lack of surgeon experience with augmented reality	35 (45.5%)
Lack of research to support the use of augmented reality surgery	20 (25.9%)
I am not concerned	10 (13%)
<i>After reading description of technologies</i>	
If you were to have shoulder orthopedic surgery, would you prefer the use of augmented reality technology?	
Prefer augmented reality technology	26 (33.8%)
No preference	36 (46.8%)
Prefer no augmented reality use in my surgery	8 (10.3%)
I still don't know what augmented reality is	7 (9.1%)
Do you think that the use of augmented reality leads to better results following shoulder orthopedic surgery in general?	
Better Results	30 (39.0%)
Equal Results	44 (57.1%)
Worse Results	3 (3.9%)
What would be your major concern regarding augmented reality in shoulder surgery?	
Increased cost	13 (16.9%)
Operation takes longer	4 (5.2%)
Lack of surgeon experience with augmented reality surgery	41 (53.2%)
Lack of research to support the use of augmented reality surgery	8 (10.4%)
I am not concerned	11 (14.3%)
Do you think that the use of augmented reality technology leads to fewer complications during or after orthopedic surgery?	
Fewer complications	27 (35.1%)
Equal complications	46 (59.7%)
More complications	4 (5.2%)
Do you think that the use of augmented reality technology leads to less pain with orthopedic surgery?	
Less pain	26 (33.8%)
Equal pain	48 (62.3%)
More pain	3 (3.9%)

Do you think that the use if augmented reality technology leads to faster recovery after orthopedic surgery?	
Faster	23 (29.9%)
Equal	52 (67.5%)
Slower	2 (2.6%)

fection rates despite a lack of clinical evidence (Ahmad et al. 2017). Pitter et al. found that patients who had a robot-assisted hysterectomy were more satisfied with their procedure compared to patients who underwent other types of hysterectomies (Pitter et al. 2014). Additionally, Abdelaal et al. investigated patient perceptions of robotics in total knee arthroplasty. Their survey revealed that patients believe robot-assisted surgery leads to more precise implant placement, improved outcomes, and faster recovery times. Similar to our study, they found that patients also expressed concerns about potential malfunctions in robotics technology (Abdelaal et al. 2023). These studies support the use of robot-assisted surgeries based on patient perceptions and experience.

However, patient education on these new technologies is imperative to improve patient understanding and expectations. Studies have shown that higher preoperative expectations are predictive of better outcomes and patient satisfaction following shoulder arthroplasty procedures (Swarup et al. 2017; Rauck et al. 2018; Henn et al. 2011; Lawrence et al. 2019). Furthermore, open communication about the surgical technique, technology used, and expectations may help enhance patient trust and confidence in their surgeon. Styron et al. found that patients that had more confidence in their surgeon and procedure preoperatively had better functional outcomes (Styron et al. 2015).

Based on our findings, the general public lacks knowledge on common technologies used in shoulder arthroplasties and harbors unrealistic expectations regarding their effects on postoperative outcomes. This study identifies important concerns regarding these baseline gaps in patient knowledge and highlights the importance of preoperative counseling to improve post-operative outcomes and patient satisfaction.

LIMITATIONS

While this study has important findings, we acknowledge several limitations. Firstly, our data was collected via a survey which has an inherent sampling bias. Since the survey was delivered electronically, there may be a bias towards individuals who are more technologically advanced. Also, our analysis showed that Asian race is independently associated with a preference for surgeons who do not utilize technology, however, we may not be able to make a strong conclusion from this finding given that there were only 5 (6.5%) respondents of Asian race in our cohort. Additionally, the survey administration only occurred in one region of the country, so it may not be generalizable to other geographical areas. Furthermore, the survey did not account for participant careers, which may impact the results. For example, healthcare workers may have more exposure to

surgical technology. Lastly, the participants lacked a pre-existing symptomatic pathology and had a younger age distribution than that of patients who typically undergo shoulder arthroplasty procedures (Longo et al. 2022). Therefore, the population surveyed may not accurately represent the patient population. However, a multivariate analysis in our study found that age was not a significant factor in surgical preference.

Furthermore, the readability of the resources provided to patients limits the study. The intraoperative navigation resources had a Flesch-Kincaide Grade Level (FKGL) of 17.4 and a Flesch Reading Ease Score (FRES) of 7.9, which correlates to a college graduate reading level. The augmented reality resource also was written at a college graduate reading level with a FKGL of 21.7 and a FRES of 0. Lastly, the robotic surgery resource had a FKGL of 15.4 and a FRES of 18.4. This also correlates to a college graduate reading level. The advanced verbiage used in these resources greatly limits the inclusivity of this study since the average American citizen has the capacity to read at an 8th grade reading level. The National Institutes of Health (NIH) recommends that patient education material not surpass a 6th grade reading level (Cotugna, Vickery, and Carpenter-Haeefe 2005; Weiss et al. 1994; Brega et al. 2015).

Future studies may provide more readable resources on the technologies or focus on responses from actual patients rather than the general public. Surgeons could also assess patient perceptions of technology before and after undergoing surgeries that utilize technology or compare post-operative patient perspectives between patients who underwent technology-assisted surgeries and those who did not.

CONCLUSION

The public appears to be unaware of various forms of technology used today in shoulder surgery and there are misperceptions regarding the outcomes with these technology-assisted surgeries. Brief descriptions of these technologies did appropriately enhance patients' understanding and expectation for these technologies applied in shoulder surgery. More patient-directed education is needed if we are to incorporate these innovative technologies in surgery and improve shared decision making. Furthermore, this may prove to be a powerful marketing tool for surgeons and hospitals.

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Table 4. Robotics

Survey Question	Responses
<i>Before reading description of technologies</i>	
Are you familiar with the use of robotic technology in orthopedic surgery?	
Very familiar	7 (9.1%)
Somewhat familiar	40 (51.9%)
Not at all	30 (39.0%)
If you were to have shoulder orthopedic surgery, would you prefer the use of robotic technology?	
Prefer robotic	17 (22.1%)
No preference	45 (58.4%)
Prefer no robotic use in my surgery	15 (19.5%)
Do you think that the use of robotic technology leads to better results following shoulder orthopedic surgery in general?	
Better Results	41 (53.2%)
Equal Results	33 (42.9%)
Worse Results	3 (3.9%)
What would be your major concern regarding robotic shoulder surgery?	
Increased cost	14 (18.2%)
Operation takes longer	2 (2.6%)
Lack of surgeon experience with robotic surgery	19 (24.7%)
Lack of research to support the use of robotic surgery	7 (9.1%)
Robot malfunctions and causes pain to you	23 (29.9%)
I am not concerned	12 (15.5%)
<i>After reading description of technologies</i>	
If you were to have shoulder orthopedic surgery, would you prefer the use of robotic technology?	
Prefer robotic technology	21 (27.3%)
No preference	36 (46.8%)
Prefer no robotic use in my surgery	14 (18.2%)
I still don't know what robotic surgery is	6 (7.8%)
Do you think that the use of robotics leads to better results following shoulder orthopedic surgery in general?	
Better Results	35 (45.5%)
Equal Results	39 (50.6%)
Worse Results	3 (3.9%)
What would be your major concern regarding robotic surgery?	
Increased cost	15 (19.5%)
Operation takes longer	3 (3.9%)
Lack of surgeon experience with robotic surgery	23 (29.9%)
Lack of research to support the use of robotic surgery	6 (7.8%)
Robot malfunctions and causes damage to you	20 (26.0%)
I am not concerned	10 (12.9%)
Do you think that the use of robotics technology leads to fewer complications during or after orthopedic surgery?	
Fewer complications	27 (35.1%)
Equal complications	45 (58.4%)
More complications	5 (6.5%)
Do you think that the use of robotics technology leads to less pain with orthopedic surgery?	
Less pain	28 (36.4%)
Equal pain	46 (59.7%)

More pain	3 (3.9%)
Do you think that the use if robotics technology leads to faster recovery after orthopedic surgery?	
Faster	28 (36.4%)
Equal	45 (58.4%)
Slower	4 (5.2%)

Table 5. Perception of surgeons who utilize technology

Survey Questions	Responses
Do you think surgeons that offer intraoperative navigation, augmented reality, or robotic technology during orthopedic surgery are better than those that do not?	
<i>Before reading description of technologies</i>	
Better	19 (24.7%)
Similar	57 (74.0%)
Worse	1 (1.3%)
<i>After reading description of technologies</i>	
Better	22 (28.6%)
Similar	53 (68.8%)
Worse	2 (2.6%)

Table 6. Population Characteristics Associated with Preference for Technology Use in Orthopedic Shoulder Procedures

	Variable, n (%)			P Value	Adjusted OR (95% CI)
	Perception of Surgeons Who Use Technology				
	Similar	Better	Worse		
Age	52 (68.4%)	22 (29.0%)	2 (2.6%)	0.390	1.016 (0.980-1.052)
Gender	---	---	----	0.860	1.209 (0.399-3.670)
Male	22 (71.0%)	8 (25.8%)	1 (3.2%)	0.764	1.163 (0.235-3.678)
Female	30 (66.7%)	14 (31.1%)	1 (2.2%)	0.656	1.023 (0.268-4.657)
Race	---	---	----	0.330	0.567 (0.164-1.032)
White	17 (70.8%)	7 (29.2%)	0 (0.0%)	0.738	1.136 (0.399-3.67)
Asian	4 (80.0%)	0 (0.0%)	1 (20.0%)	0.042*	0.049 (0.003-0.867)
Black	15 (62.5%)	8 (33.3%)	1 (4.2%)	0.931	1.002 (0.249-4.04)
Hispanic	13 (68.4%)	6 (31.6%)	0 (0.0%)	0.909	1.165 (0.262-5.180)
Other	3 (75.0%)	1 (25.0%)	0 (0.0%)	0.963	0.954 (0.785-10.873)
Education Level	---	---	----	0.500	1.145 (0.245-0.865)
Some high school	2 (66.7%)	1 (33.3%)	0 (0.0%)	0.965	0.917 (0.771-10.913)
High school	6 (66.7%)	3 (33.3%)	0 (0.0%)	0.869	0.778 (0.048-12.692)
Bachelor's	23 (65.7%)	10 (28.6%)	2 (5.7%)	0.932	1.018 (0.195-5.31)
Trade School†	0 (0.0%)	2 (100.0%)	0 (0.0%)	0.979	1.143 (0.165-7.36)
Master's Degree	16 (84.2%)	3 (15.8%)	0 (0.0%)	0.302	0.485 (0.122-1.919)
Ph.D or Higher	5 (62.5%)	3 (37.5%)	0 (0.0%)	0.830	1.208 (0.214-6.773)

Bolded numbers indicate significance ($p < 0.05$); Reference categories were used as reference in ordinal logistic regression analysis.



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APPENDIX

Survey Questions

1. Date of Birth
2. Gender
 - a. Male
 - b. Female
3. Race
 - a. White
 - b. Black
 - c. Hispanic
 - d. Asian
 - e. Other
4. Education Level
 - a. Some High School
 - b. High School
 - c. Bachelor's Degree
 - d. Master's Degree
 - e. PhD or higher
 - f. Trade School
 - g. Prefer not to say
5. Have you ever had shoulder surgery before?
 - a. Yes
 - b. No
6. When it comes to technology, what best describes you?
 - a. I am skeptical of new technologies, and use them only when I have to
 - b. I am usually one of the last people I know to use new technologies
 - c. I usually use new technologies when most people I know do
 - d. I like new technologies and use them before most people I know
 - e. I love new technologies and am among the first to experiment with and use them
7. Are you familiar with the use of computer-navigated surgery technology in orthopedic surgery?
 - a. Very familiar
 - b. Somewhat familiar
 - c. Not at all
8. If you were to have shoulder orthopedic surgery, would you prefer the use of computer-navigated surgery technology?
 - a. Prefer computer-assisted technology
 - b. No preference
 - c. Prefer non-computer-assisted surgery
9. Are you familiar with the use of augmented reality technology in orthopedic surgery?
 - a. Very familiar
 - b. Somewhat familiar
 - c. Not at all
10. If you were to have shoulder orthopedic surgery, would you prefer the use of augmented reality technology?
 - a. Prefer augmented reality technology
 - b. No preference
 - c. Prefer non-augmented reality surgery
11. Are you familiar with the use of robotic technology in orthopedic surgery?
 - a. Very familiar
 - b. Somewhat familiar
 - c. Not at all
12. If you were to have shoulder orthopedic surgery, would you prefer the use of robotic technology?
 - a. Prefer robotic
 - b. No preference
 - c. Prefer non-robotic use in my surgery
13. Do you think that the use of intraoperative navigation technology leads to better results following shoulder orthopedic surgery in general?
 - a. Better results
 - b. Equal results
 - c. Worse results
14. Do you think that the use of augmented reality technology leads to better results following shoulder orthopedic surgery in general?
 - a. Better results
 - b. Equal results
 - c. Worse results
15. Do you think that the use of robotic technology leads to better results following shoulder orthopedic surgery in general?
 - a. Better results
 - b. Equal results
 - c. Worse results
16. What would be your major concern regarding intraoperative navigation shoulder surgery?
 - a. Increased cost
 - b. Operation takes longer
 - c. Lack of surgeon experience with intraoperative navigation surgery
 - d. Lack of research to support the use of intraoperative navigation surgery
 - e. I am not concerned
17. What would be your major concern regarding augmented reality shoulder surgery?
 - a. Increased cost
 - b. Operation takes longer
 - c. Lack of surgeon experience with augmented reality surgery
 - d. Lack of research to support the use of augmented reality surgery
 - e. I am not concerned
18. What would be your major concern regarding robotic surgery?
 - a. Increased cost
 - b. Operation takes longer
 - c. Lack of surgeon experience with robotic surgery
 - d. Lack of research to support the use of robotic surgery
 - e. Robot malfunctions and causes damage to you
 - f. I am not concerned
19. Do you think surgeons that offer intraoperative navigation, augmented reality, or robotic technology during orthopedic surgery are better than those that do not?

- a. Better
- b. Similiar
- c. Worse

Intraoperative navigation is a technology that connects preoperative imaging with real-time intraoperative instrument guidance to guide implant placement. This platform combines surgeon expertise with a computer system to perform your shoulder surgery with a goal of more precise placement of shoulder replacement components personalized to your unique anatomy. There is debate if the use of intraoperative navigation leads to better results for patients.

20. If you were to have shoulder orthopedic surgery, would you prefer the use of intraoperative navigation technology?
 - a. Prefer intraoperative navigation technology
 - b. No preference
 - c. Prefer non intraoperative navigation surgery
 - d. I still don't know what intraoperative navigation technology is
21. Do you think that the use of intraoperative navigation technology leads to better results following shoulder orthopedic surgery in general?
 - a. Better results
 - b. Equal results
 - c. Worse results
22. What would be your major concern regarding intraoperative navigation shoulder surgery?
 - a. Increased cost
 - b. Operation takes longer
 - c. Lack of surgeon experience with intraoperative navigation surgery
 - d. Lack of research to support the use of intraoperative navigation surgery
 - e. I am not concerned
23. Do you think that the use of intraoperative navigation technology leads to fewer complications during or after orthopedic surgery?
 - a. Fewer complications
 - b. Equal complications
 - c. More complications
24. Do you think that the use of intraoperative navigation technology leads to less pain with orthopedic surgery?
 - a. Less pain
 - b. Equal pain
 - c. More pain
25. Do you think that the use of intraoperative navigation technology leads to faster recovery after orthopedic surgery?
 - a. Faster
 - b. Equal
 - c. Slower
26. If you were to have shoulder orthopedic surgery, would you prefer the use of augmented reality technology?
 - a. Prefer augmented reality technology
 - b. No preference
 - c. Prefer non-augmented reality surgery
 - d. I still don't know what augmented reality is
27. Do you think that the use of augmented reality technology leads to better results following shoulder orthopedic surgery in general?
 - a. Better results
 - b. Equal results
 - c. Worse results
28. What would be your major concern regarding augmented reality shoulder surgery?
 - a. Increased cost
 - b. Operation takes longer
 - c. Lack of surgeon experience with augmented reality surgery
 - d. Lack of research to support the use of augmented reality surgery
 - e. I am not concerned
29. Do you think that the use of augmented reality technology leads to fewer complications during or after orthopedic surgery?
 - a. Fewer complications
 - b. Equal complications
 - c. More complications
30. Do you think that the use of augmented reality technology leads to less pain with orthopedic surgery?
 - a. Less pain
 - b. Equal pain
 - c. More pain
31. Do you think that the use of augmented reality technology leads to faster recovery after orthopedic surgery?
 - a. Faster
 - b. Equal
 - c. Slower
32. If you were to have shoulder orthopedic surgery, would you prefer the use of robotic technology?
 - a. Prefer robotic
 - b. No preference
 - c. Prefer non-robotic use in my surgery
 - d. I still don't know what it is
33. Do you think that the use of robotic technology leads to better results following shoulder orthopedic surgery in general?
 - a. Better results
 - b. Equal results
 - c. Worse results

Robotic surgery, also called robot-assisted surgery, is carried out using mechanical arms controlled by the surgeon and bearing surgical instruments. It allows surgeons to perform many types of complex procedures with more precision, exibility and control than is possible with conventional techniques. There is debate if the use of robotic assisted leads to better results for patients.

Augmented reality is a headset worn by surgeons which enables surgeons to view three-dimensional holographic images of a patient's anatomy created from X-rays or computed tomography scans during surgery.

34. What would be your major concern regarding robotic surgery?
 - a. Increased cost
 - b. Operation takes longer
 - c. Lack of surgeon experience with robotic surgery
 - d. Lack of research to support the use of robotic surgery
 - e. Robot malfunctions and causes damage to you
 - f. I am not concerned
35. Do you think that the use of robotic technology leads to fewer complications during or after orthopedic surgery?
 - a. Fewer complications
 - b. Equal complications
 - c. More complications
36. Do you think that the use of robotic technology leads to less pain with orthopedic surgery?
 - a. Less pain
 - b. Equal pain
 - c. More pain
37. Do you think that the use of robotic technology leads to faster recovery after orthopedic surgery?
 - a. Faster
 - b. Equal
 - c. Slower
38. Do you think surgeons that offer intraoperative navigation, augmented reality, or robotic technology during orthopedic surgery are better than those that do not?
 - a. Better
 - b. Similar
 - c. Worse