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Navigation in total knee arthroplasty: the resident's friend or foe?

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INTRODUCTION

Total knee arthroplasty (TKA) has been demonstrated to have excellent outcomes in patients with osteoarthritis of the knee.[1] Computer-assisted navigation (CAN) systems have been developed to improve the accuracy of measured resection and component positioning.[1,2] CAN in TKA have shown lower risk of component malalignment.[3]

Worldwide, the rate of navigation in TKA varies, from 3% in the United Kingdom[4] to 30.8% in Australia.[5] In our institution, 74.9% of all primary TKAs performed are navigated. While the benefits and disadvantages of navigation in TKA have been well established, its effect on Orthopaedic residents' learning and competency in performing a TKA have yet to be studied. Due to the navigation-heavy load in our institution, our residents' learning of the basic principles of TKA may also be unique.

The aim of our study is to evaluate the perception of navigation in TKA amongst Orthopaedic residents and its effect on their perceived competency in performing a TKA. To our knowledge, this is the first study investigating the relationship between CAN TKA and Orthopaedic residency training.

METHODS

A cross-sectional descriptive survey was created to study the perception of CAN in TKA amongst Orthopaedic residents in a single institution. We included all residents who had undergone a minimum of one rotation with the adult reconstruction service, where they would have had the opportunity to perform both conventional and navigated TKA as part of their learning goals.

A self-administered questionnaire (Appendix) was created and placed on an online platform, where residents could maintain anonymity. Residents were sent an email where they could access the online platform and complete the questionnaire. Responding to the questionnaire was voluntary, and anonymity was emphasized in the email in order to avoid response bias. Submission of response was interpreted as residents' implied consent to participate. The questionnaire involved 3 parts, which included questions relating to: 1) their perceptions of navigation and conventional TKA; 2) their attitudes towards navigation, and 3) an objective assessment of their knowledge regarding a conventional TKA. Where applicable, a 5-point Likert scale was used to quantify the residents' responses to the statements and questions posed.

The study was performed in accordance with the ethical standards laid down in the most recent version of the 1964 Declaration of Helsinki. The Domain Specific Review Board (DSRB) of the National Healthcare Group (NHG) had reviewed the study, and an exemption was granted (2019/01252).

Statistical analyses were done using GraphPad Prism 5 (Graphpad software Inc., San Diego, CA). Spearman's rank correlation coefficient (rho) was calculated to assess the inter-item correlation between the part 1 components of the questionnaire. A rho value of greater than 0 was considered as a positive correlation, and the closer it is to +1 was considered as a strong positive correlation. A probability value (p), representing the significance of correlation, of less than 0.05 was considered statistically significant.

RESULTS

Our sample population included 28 out of 34 eligible residents, with a response rate of 82.4%. All of the included residents had at least one rotation of 4 to 6 months with the adult reconstruction service. During their rotation, all residents had the opportunity to actively plan for, assist and participate in conventional and navigated TKA surgeries, under the supervision of a senior surgeon.

For the first part of the questionnaire, the mean Likert scale score for statements regarding navigated TKA ranged from 3.46 to 4.04, with residents responding that they agreed, or strongly agreed, with the statements given (Fig. 1, Table I). These statements included their perceptions of navigation in TKA, indicating a generally positive perception of navigation as an adjunct to TKA. Residents also agreed that they were predominantly exposed to TKA utilizing navigation (mean Likert scale of 3.79 ± 0.92), and that they understood the concepts of navigation (mean Likert scale of 3.96 ± 0.43). However, these residents' overall perception regarding their competency to carry out a TKA on their own using navigation (question 9) was 2.71 ± 0.85 on a 5-point Likert scale. There was a weak correlation with their perceptions of navigated total knee replacement surgery, and their overall perceived competency at the end of their rotation (Table II).

The second part of the questionnaire included questions regarding conventional TKA surgery. All 28 residents (100%) had assisted in, or performed, a conventional TKA. 26 residents (92.9%) understood how to achieve the main goal of satisfactory knee alignment in a conventional TKA. However, despite that, the overall perception regarding their competency in performing a conventional total knee replacement was 2.71 ± 0.81 on the 5-point Likert scale, indicating that they either were neutral, or did not feel competent performing a conventional TKA independently. The main reason for their perception of incompetency was a lack of exposure and experience in conventional TKA, as a greater proportion of their residency training with TKA involved the use of navigation.

A large majority of residents, 78.6% (22 residents), agreed that navigation for TKA was advantageous as a teaching tool. Other advantages cited were its utility in difficult cases, such as severe varus or valgus knee deformities, and achieving a potentially better knee alignment. The top two disadvantages mentioned by the residents included cost and a steep learning curve.

The majority of residents (78.6%, 22 residents) opined that CAN TKA was the better technique compared to conventional.

The last part of the questionnaire objectively analysed the residents' ability to adequately plan and carry out a conventional TKA. 71.4% (20 residents) could identify the femoral landmark for the drilling of an intramedullary rod, while 96.4% (27 residents) were correct in the coronal cut planning for the femur when given a long leg standing radiograph. However, only 53.6% (15 residents) were correct in identifying the landmark for appropriate placement of the tibia jig at the centre of the ankle, and only 64.3% (18 residents) identified the tibia jig placement on the junction between the middle and medial third of the tibial tubercle correctly.

On dividing the results of the residents into junior residents (years one to three) and senior residents (years four to six), senior residents were noted to fare better in the last part of the questionnaire. 84.2% of senior residents could identify the femoral landmark for drilling of an intramedullary rod, compared to 44.4% of junior residents. Likewise, 100% of senior residents were correct in the femur coronal cut planning, compared to 88.9% of junior residents. 68.4% of senior residents could identify the landmarks for the placement of the tibia jig (ankle and tibial tubercle) compared to 22.2% and 55.6% of junior residents.

DISCUSSION

While the success of a TKA is contributed by many factors, post-operative malalignment of greater than 3 degrees from the mechanical axis has been widely associated with an increased risk of failure,(6,7) due to abnormal tibiofemoral tracking and altered stresses on the prosthesis.(3) CAN in TKA was developed to improve the accuracy of bony resection, and hence the eventual overall knee alignment.(8,9) Studies have since demonstrated that navigation allows for improved implant alignment, reducing the number of alignment outliers.(10)

Although its benefits have been well reported, the effect of increasing use of navigation in TKA on Orthopaedic residency training has not been previously studied. In spine surgery, a prior study found that residents predominantly exposed to navigation were more comfortable with it compared to freehand for pedicle screws insertion, and up to a third of them were unable to correctly identify anatomical landmarks.[(11)]

In our institution, Orthopaedic residents in the adult reconstruction service are able to assist and perform both navigation-assisted and conventional TKA. However, our practice is unique in that up to 75% of primary TKAs are performed with CAN. Our study aim was hence to investigate the perception of residents and their attitudes towards navigation.

The survey results showed that most residents felt they understood the concepts of navigation in TKA. They felt that it was easy to use navigation to make measured resections, and were confident of achieving satisfactory alignment, even for knees with severe deformities. Their confidence and positive perceptions are likely to have been influenced by significant exposure to navigation in their training. However, despite their overall positive attitude, they did not perceive themselves highly as being able to perform a navigated TKA independently. These results were similar for conventional TKA, with residents agreeing that they understood the principles of conventional TKA, yet did not feel competent in doing one independently. The similarities in perceptions for the both techniques thus show that the residents' perceived competency may not be solely due to a differential exposure in training with regards to navigation versus conventional TKA. While navigation is a helpful adjunct in improving alignment of the knee, there are other factors involved in a successful TKA, such as soft tissue balancing, and crucially, the decision making involved. These results show that whilst our residents are confident about the abilities of navigation, they are cognisant that navigation alone is not sufficient to ensure a good outcome during a TKA. Consequently, this can also guide teaching faculty to adjust the way they teach and aid resource allocation. The focus may then be shifted to areas they feel less confident in.

We believe that navigation still has its advantages as a teaching tool for residents, if used correctly and with due diligence to pre-operative planning and intra-op verification using anatomical landmarks. Apart from the benefits of navigation to surgeons, use of such technology while allowing residents to operate under supervision ensures that patients' outcomes are not compromised. For the resident, navigation is advantageous in that real-time feedback is given after performing each bone cut, allowing the resident to have instant feedback and the ability to correct any errors immediately.(12,13) This also improves the residents' understanding and consequences of the operative steps. There is also evidence that after the use of navigation-assisted surgery, even experienced surgeons showed improved accuracy in freehand placement of components.(14)

It is known that arthroplasty has a significant learning curve, and surgeon as well as case volume has been shown to be predictors of outcomes after TKA.(15,16) This is also noted in our results, where senior residents fared better in the last part of our questionnaire compared to junior residents. With navigation, the learning curve can be reduced, as demonstrated by other studies in a setting of hip resurfacing.(17) Early improved performance in total hip arthroplasty has also been noted when training was done with navigation, and trainees' learning was not compromised.(18)

As residents are confident with navigation's abilities to help with the accuracy of bony cuts, this will allow the resident to focus on other aspects of the surgery, such as the approach, soft tissue releases and balancing, and improve their surgical dexterity and confidence with the procedure. This gain in operative confidence is invaluable, especially when they subsequently embark on their individual careers as an independent surgeon in arthroplasty. Navigation can thus help to "bridge the gap" from an unsure resident, to a confident and competent surgeon.

Despite the benefits for training, navigation still ultimately remains an adjunct, and we must be mindful to avoid over-reliance on such technology in the event that navigation is not available, or it fails intra-operatively. In such cases, the surgeon needs to be able to confidently continue with a standard TKA. As one of the drawbacks of navigation, the ability of residents to carry out pre-operative planning with long leg radiographs may also be affected, as navigation systems calculate the angle of the distal femoral cut intra-operatively.

This corroborated with the results of the questionnaire regarding the identification of femoral and tibial landmarks. In our study, the two main reasons why residents felt they were not competent with performing a conventional TKA was the lack of exposure to conventional TKA, as well as a higher number of navigated TKA being performed during their rotation. Other disadvantages of navigation are its increased cost,(19) and a lack of evidence showing a clear superiority in functional outcomes or satisfaction rates over conventional TKA.(20,21) In addition, though navigated TKAs show improved accuracy in component alignment, there are still no conclusive evidence of clinical benefit compared to conventional TKAs in terms of decreased long-term revision rate or patient-reported outcome measures.(2)

Based on our results, additional tools for teaching residents such as sawbone workshops may be incorporated. In order for residents to correlate navigation with conventional TKA, and to demonstrate the principles of both, such workshops should include the use of both conventional instrumentation as well as navigation. As a follow-up study, it will be useful to be able to repeat the survey for the residents who have turned attending next year, for example, to see if there have been any changes to their perceptions and attitudes regarding navigation when they start independent practice. In addition, another survey for the lead surgeon can be developed in the follow up study, studying their perspectives of navigated TKA and its impact on teaching residents. This can then be correlated with residents' perceptions of navigated TKA.

To the best of our knowledge, this study is the first of its kind to examine the perceptions of Orthopaedic residents on navigation in TKA. However, the study does have its limitations. Objective evaluation of the residents' competency with conventional or navigated TKA surgeries could not be done during an actual surgery. Further objective measures can be evaluated such as assessing and comparing radiographically the post-operative alignment of the same resident's completed conventional and navigated TKA. Also, as residents were exposed to both navigated and conventional TKAs from the start of their residency training, it was not possible to attain a comparison of an improvement in knowledge in competency prior and after the use of navigation.

The results may have been subject to reporting bias, as they were largely dependent on their personal perception of their comfort level and confidence. The training institution also has a high rate of navigated primary TKA (up to 75%), likely skewing the training volume of residents performing conventional TKA. As such, this may have created a bias in perception, understanding and competency in performing a conventional TKA._In addition, it is a single-centre study which does not reflect the perception of Orthopaedic residents in general.

In conclusion, our study shows that majority of residents have positive perceptions of navigation in TKA and are confident of its abilities. Hence, navigation can still be a useful tool for the young surgeon to learn and gain operative confidence. However, there must still be an avoidance of over-reliance on such technology. Whilst navigation is ultimately an adjunct, it is one that is likely here to stay, and our efforts in teaching residents should allow them to be competent, flexible, and confident in both conventional and navigated TKA – the modern surgeon of the future.

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Table I: Questionnaire responses including mean Likert scale scores

S. No	Given statement	Mean Likert scale score/standard deviation	
PART 1A			
1	Adult reconstruction (Hip and Knee) navigation technology has revolutionized knee replacement surgery	4.04 ± 0.58	
2	I understand the concepts of navigation in total knee replacement.	3.96 ± 0.43	
3	I am predominantly exposed to total knee replacement surgeries using navigation.	3.79 ± 0.92	
4	I am sure about the anatomy of the knee and possible anatomical variants	3.96 ± 0.33	
5	I feel that the making measured resection cuts and balancing the knee while using navigation is simple.	3.75 ± 0.64	
6	I can achieve satisfactory knee alignment using navigation.	3.93 ± 0.54	
7	I am confident of satisfactory alignment of the knee using navigation even in severe varus/valgus knees	3.46 ± 0.88	
8	I am extremely satisfied with the surgery using navigation.	3.75 ± 0.70	
9	At the end of your training, how competent are you in carrying out total knee replacement on your own using navigation (on a scale of 5)?	2.71 ± 0.85	
PART 1B			
		Yes	**No**
1	Have you carried out or assisted a conventional total knee replacement?	100%	0%
2	Do you understand how to get satisfactory knee alignment in conventional total knee replacement?	92.9%	7.1%
3	At the end of your training, how competent are you in performing a conventional total knee replacement (on a scale of 5)?	2.71 ± 0.81	
4	If you feel that you are not competent in performing a conventional total knee replacement, please give your reason?	**Lack of exposure and experience** 24.1%	**More navigated cases than conventional cases** 13.8%
PART 2			
1	Do you think AR navigation has advantages as a teaching tool?	**Yes** 78.6%	**No** 21.4%
2	In your opinion, what are the two main advantages of navigation in total knee replacement?		
	1. Ease of use	12 %	
	2. Better alignment of the knee	23.7%	
	3. Decreases stress/anxiety for determining resections	21.4%	
	4. Benefits difficult cases (E.g. severe varus or valgus)	67.3%	

3	In your opinion, what are the two main disadvantages of navigation in total knee replacement? 1. Availability 2. Cost 3. Surgical time 4. Learning Curve	 17.8% 85.7% 35.7% 46.4%	
4	In your opinion, which is the best technique?	**Navigation** 78.6%	**Conventional** 21.4%
PART 3 - Please label the landmarks for a conventional total knee replacement			
FEMUR			
1	Please name the landmark on the femur for drilling of the hole for the IM rod in a total knee replacement below	**Correct** 71.4%	**Wrong** 28.6%
2	What is the most appropriate coronal plan cut for the femur based on this imaging? A) 0 degree cut B) Varus 7 degree cut C) Valgus 7 degree cut D) Flexion 7 degree cut	**Correct** 96.4%	**Wrong** 3.6%
TIBIA			
1	Please name the landmark on the tibia where you would place part A of this tibia EM jig	**Correct** 53.6%	**Wrong** 46.4%
2	Please label the landmark on the tibia where you would place part B of this tibia EM jig	**Correct** 64.3%	**Wrong** 35.7%

Table II: Inter-item correlation matrix for questionnaire's Part 1A components

		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1	*Rho*	1.000	0.454*	0.515**	0.202	0.239	0.127	0.075	0.384*	0.275
	p		0.015	0.005	0.304	0.220	0.519	0.706	0.044	0.156
Q2	*Rho*	0.454*	1.000	0.249	0.506**	0.112	0.148	0.055	0.092	0.083
	p	0.015		0.202	0.006	0.571	0.453	0.779	0.641	0.676
Q3	*Rho*	0.515**	0.249	1.000	0.390*	0.289	0.137	0.259	0.407*	0.010
	p	0.005	0.202		0.040	0.136	0.488	0.183	0.032	0.960
Q4	*Rho*	0.202	0.506**	0.390*	1.000	0.576**	0.391*	0.440*	0.430*	0.108
	p	0.304	0.006	0.040		0.001	0.040	0.019	0.023	0.584
Q5	*Rho*	0.239	0.112	0.289	0.576**	1.000	0.510**	0.624**	0.506**	0.162
	p	0.220	0.571	0.136	0.001		0.006	0.000	0.006	0.411
Q6	*Rho*	0.127	0.148	0.137	0.391*	0.510**	1.000	0.635**	0.600**	0.350
	p	0.519	0.453	0.488	0.040	0.006		0.000	0.001	0.068
Q7	*Rho*	0.075	0.055	0.259	0.440*	0.624**	0.635**	1.000	0.528**	0.146
	p	0.706	0.779	0.183	0.019	0.000	0.000		0.004	0.457
Q8	*Rho*	0.384*	0.092	0.407*	0.430*	0.506**	0.600**	0.528**	1.000	0.298
	p	0.044	0.641	0.032	0.023	0.006	0.001	0.004		0.123
Q9	*Rho*	0.275	0.083	0.010	0.108	0.162	0.350	0.146	0.298	1.000
	p	0.156	0.676	0.960	0.584	0.411	0.068	0.457	0.123	

Rho: Spearman's rank correlation coefficient (Correlation is considered stronger when "rho" values are close to 1)
p: probability value (A probability value of less than 0.05 is considered statistically significant)
*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

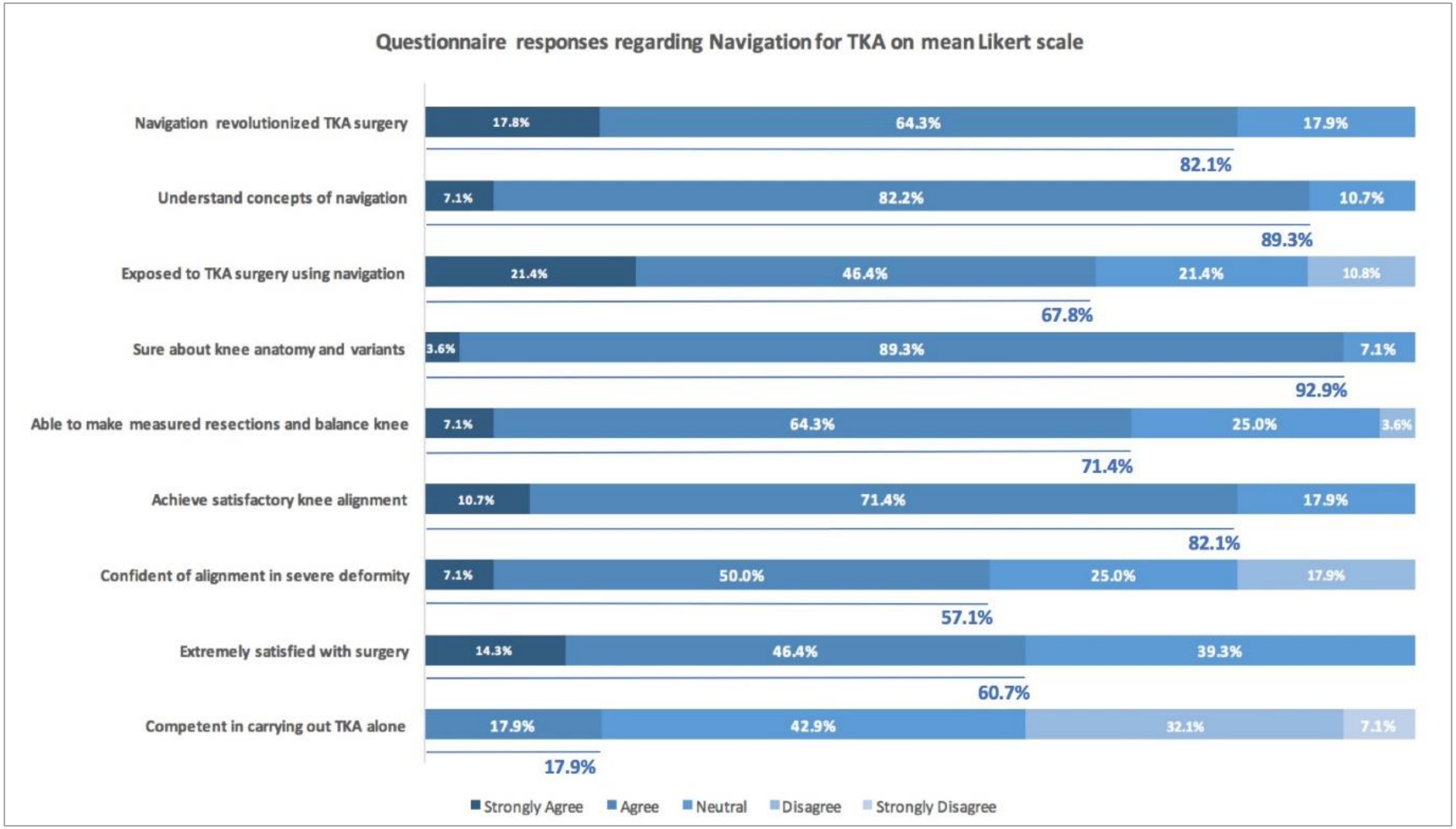


Fig. 1 Questionnaire responses regarding Navigation for TKA on mean Likert scale

APPENDIX

Questionnaire

Year of orthopaedic training (or practice) –

Does your training include active participation in total knee replacement procedures?

Yes [ ] No [ ]

Are you involved in knee measured resections and knee balancing during surgeries?
Yes [ ] No [ ]

Which method of total knee replacement are you more familiar with? (Please tick)

a. Conventional technique [ ]
b. Navigation [ ]

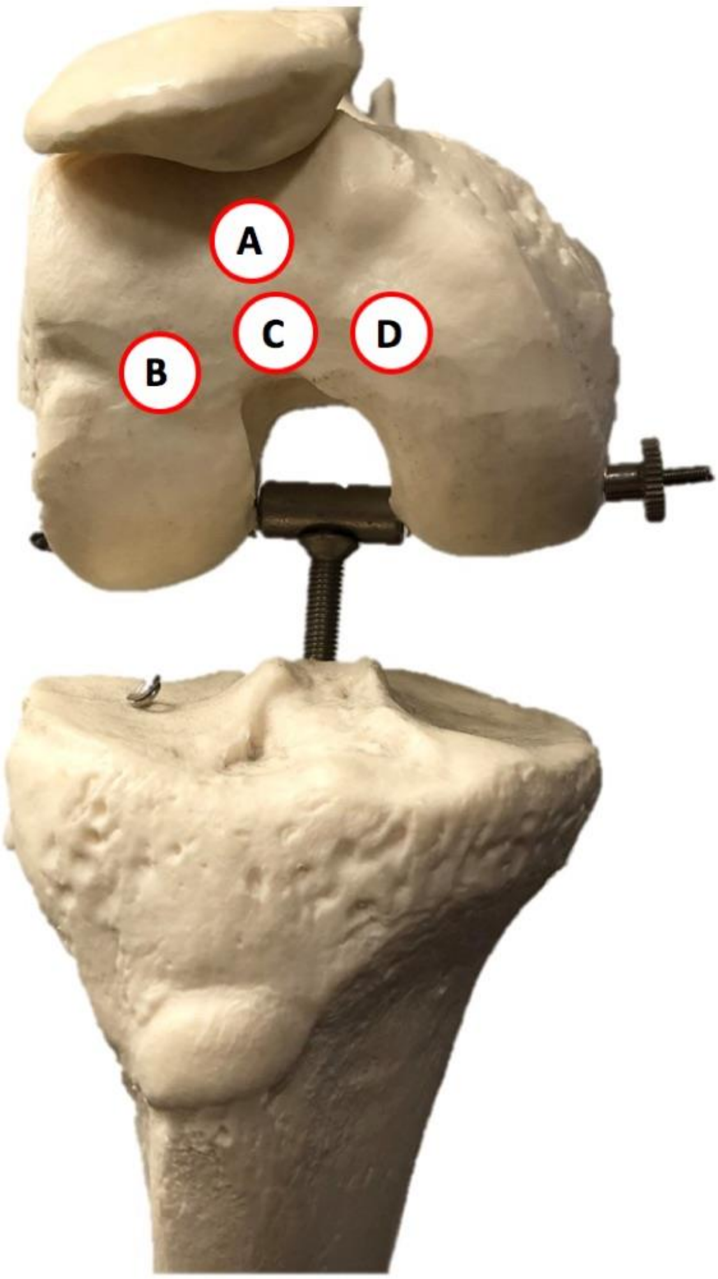
If you have chosen one of the above, are you aware of the other method?

Yes [ ] No [ ]

Questionnaire
(for those more familiar with using navigation for total knee replacement)

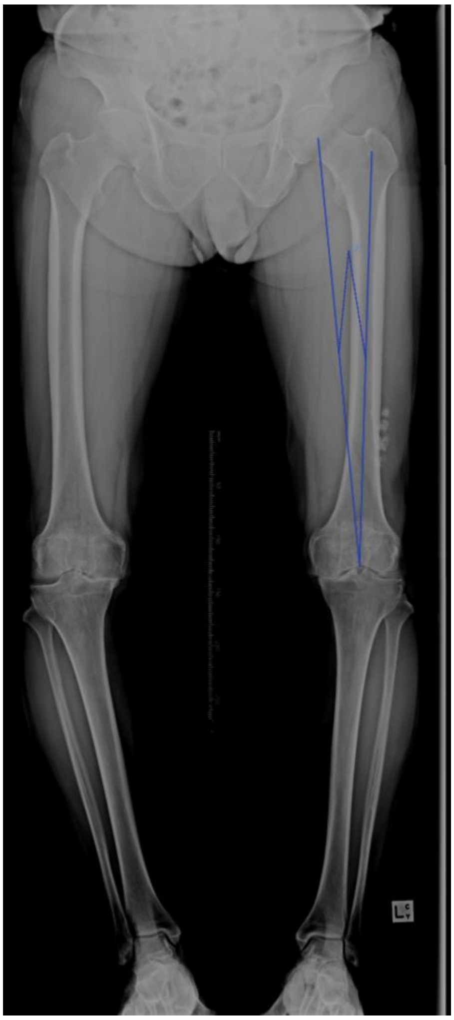
Q. No	**Statement** (Please denote your agreement to the given statement on a scale of 5)	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
	Part 1					
1	Adult reconstruction (Hip and Knee) navigation technology has revolutionized knee replacement surgery.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
2	I understand the concepts of navigation in total knee replacement.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
3	I am predominantly exposed to total knee replacement surgeries using navigation.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
4	I am sure about the anatomy of the knee and possible anatomical variants.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
5	I feel that the making measured resection cuts and balancing the knee while using navigation is simple.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
6	I can achieve satisfactory knee alignment using navigation.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
7	I am confident of satisfactory alignment of the knee using navigation even in severe varus/valgus knees	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
8	I am extremely satisfied with the surgery using navigation.	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]

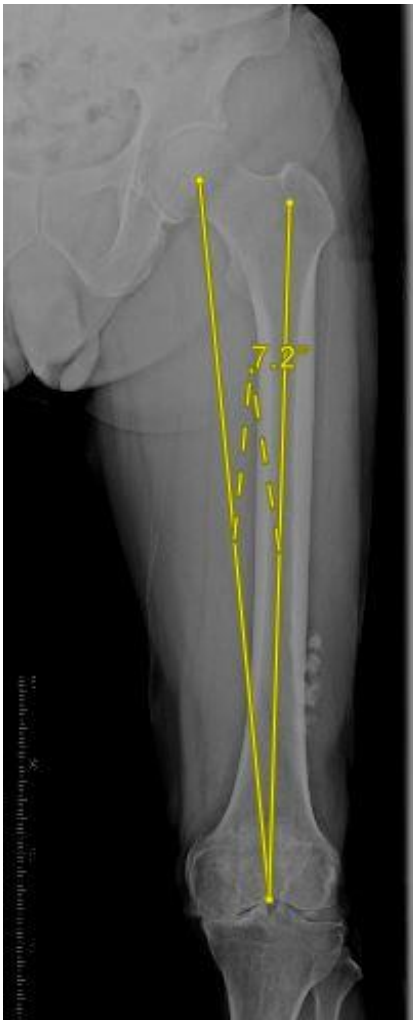
9	At the end of your training, how competent are you in carrying out total knee replacement on your own using navigation (on a scale of 5)?	**Not at all**	**A Little**	**Rather**	**Much**	**Very much**
		1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
			Part 2			
1	Have you carried out or assisted a conventional total knee replacement?	Yes [ ] No [ ]				
2	Do you understand how to get satisfactory knee alignment in conventional total knee replacement?	Yes [ ] No [ ]				
3	At the end of your training, how competent are you in performing a conventional total knee replacement (on a scale of 5)?	1 [ ]	2 [ ]	3 [ ]	4 [ ]	5 [ ]
4	If you feel that you are not competent in performing a conventional total knee replacement, please give your reason?					
			Part 3			
1	Do you think AR navigation has advantages as a teaching tool?	Yes [ ] No [ ]				
2	In your opinion, what are the two main advantages of navigation in total knee replacement? (Please tick)	1. Ease of use [ ] 2. Better alignment of the knee [ ] 3. Decreases stress/anxiety for determining resections [ ] 4. Benefits difficult cases (E.g. severe varus or valgus) [ ] 5.. Others (please specify) ______________________				
3	In your opinion, what are the two main disadvantages of navigation in total knee replacement? (Please tick)	1. Availability [ ] 2. Cost [ ] 3. Surgical time [ ] 4. Learning Curve [ ] 5. Others (please specify) ______________________				
4	In your opinion, which is the best technique?					

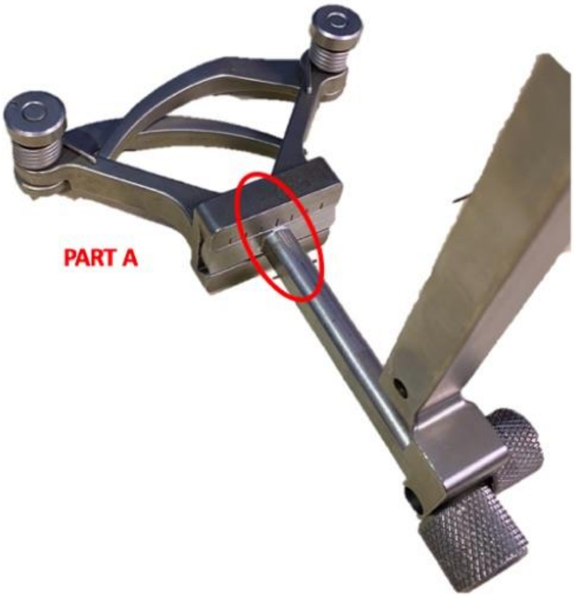
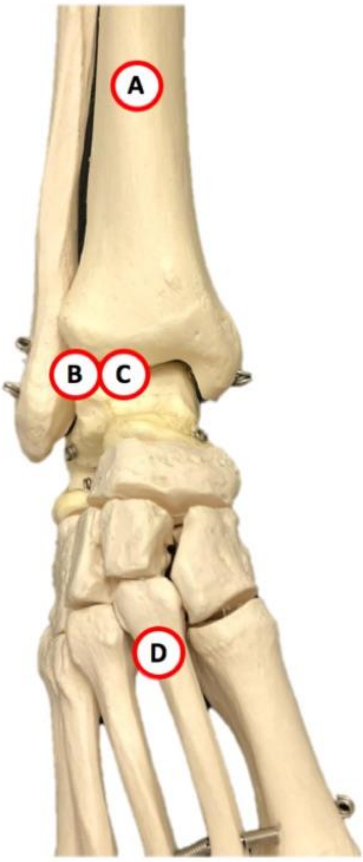
	Part 4
	Please label the landmarks for a conventional total knee replacement in the
	Femur
1.	Please name the landmark on the femur for drilling of the hole for the IM rod in a total knee replacement below 

2. What is the most appropriate coronal plan cut for the femur based on this imaging?

A) 0 degree cut
B) Varus 7 degree cut
C) Valgus 7 degree cut
D) Flexion 7 degree cut





	Tibia
1.	Please name the landmark on the tibia where you would place part A of this tibia EM jig  

2.	Please label the landmark on the tibia where you would place part B of this tibia EM jig