

The Use of Computer Navigation and Patient Specific Instrumentation in Shoulder Arthroplasty: Everyday Practice, Just for Special Cases or Actually Teaching a Surgeon?

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ABSTRACT

Background: The use of computer assisted surgery, navigation (NAV) in shoulder arthroplasty is still under discussion, regarding the clinical outcome and prosthesis longevity, especially when combining these factors with cost, time and surgeon's experience. Beside the NAV, there has been in use patient-specific instrumentation (PSI) as an additional tool for more precise glenoid implant position. Surgical NAV and PSI for glenoid implant positioning in anatomic and reverse total shoulder arthroplasty are in last years under observation and discussion. **Objective:** To critically review and evaluate the current literature regarding the use of computer navigation and PSI in shoulder arthroplasty. **Methods:** Critical review of the existing literature. **Results:** Cost-effectiveness, prosthesis longevity and revision arthroplasty rate have not yet been proven clinically. Moreover, heterogeneity is high in studies that include different positioning systems (NAV, PSI and standard instrumentation). Heterogeneity is due to differences in surgical technique, implants, surgeon's expertise, radiographic image analysis technique. **Conclusion:** The use of navigation systems and PSI should be clinically proven in the shoulder arthroplasty. Independent experts' opinion and independent high level studies lack at the moment. There will be still a lot of talk regarding this topic in future.

Keywords: computer assisted surgery, arthroplasties, patient specific instrumentation.

1. NAVIGATION AND PATIENT-SPECIFIC INSTRUMENTATION IN SHOULDER ARTHROPLASTY

Computer assisted orthopaedic surgery, computer assisted navigation (NAV) was first used in neuro (spinal) surgery (1), then hip and knee (1-4), and in the last years also in shoulder arthroplasty, which is still under discussion, regarding the clinical outcome and prosthesis longevity, especially when combining these factors with cost, time and surgeon's experience. It is known that navigation is well suited for use in orthopedic surgery, because bony and anatomic relationships remain stable while making the image and performing the surgery (2). However, for what reason is it used, must be discussed.

Beside the NAV, there has been in use patient-specific instrumentation (PSI) as an additional tool for more precise glenoid implant position.

The efficacy of these systems at improving radiographic outcomes has been investigated in a number of controlled and uncontrolled studies, with varying sample size, methodological quality, and results (5, 6).

Positioning of the glenoid component is one of the most challenging steps in shoulder arthroplasty, and prosthesis longevity is considered highly dependent on accurate positioning (5, 6). This is very important due to variations in scapula-humerus morphology. Surgical navigation and patient-specific instruments for glenoid implant positioning in anatomic and reverse total shoulder arthroplasty are in last years under observation and discussion (6).

Navigation is speeding up the learning curve (5), and what afterwards? Should it be used afterwards, for every case or only for special cases (more difficult ones: fractures, revi-

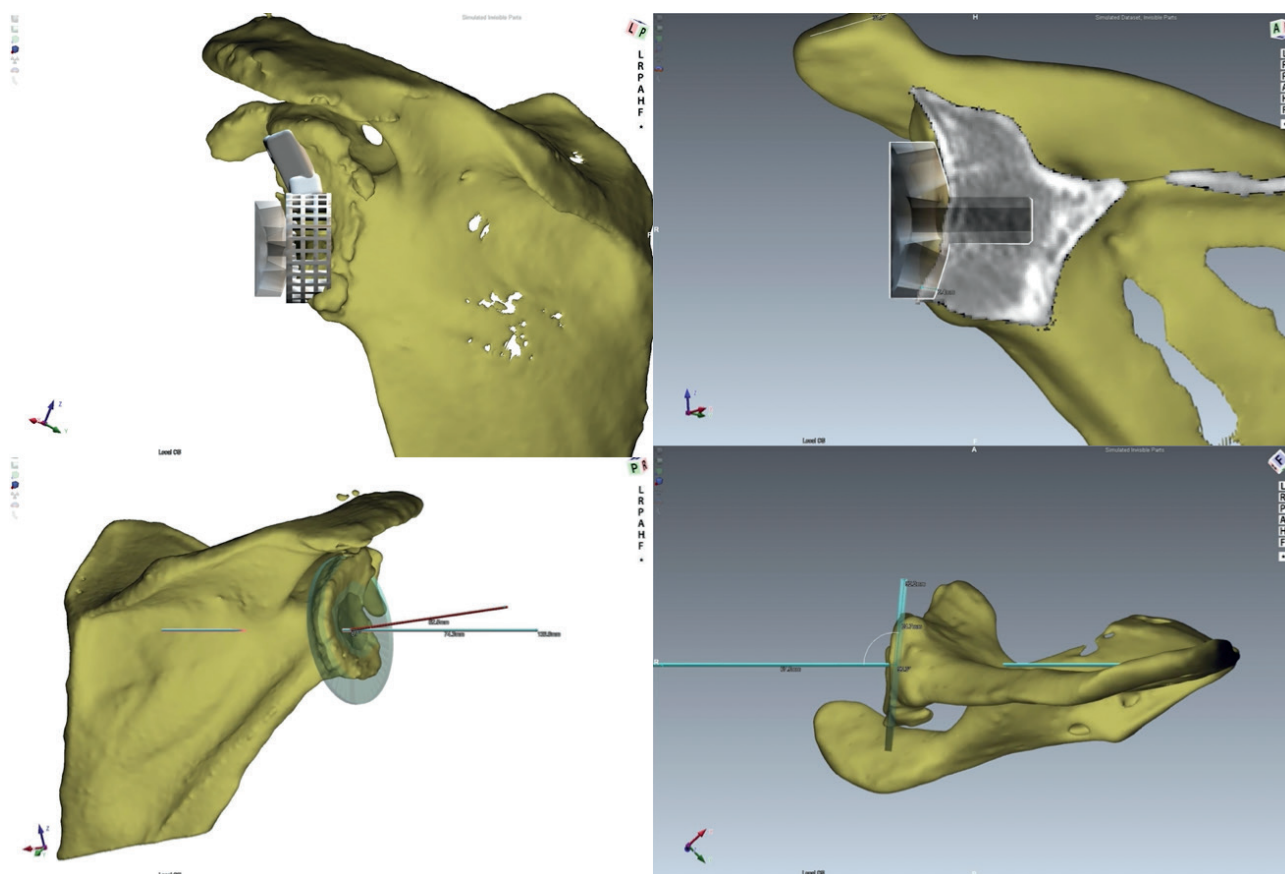


Figure 1. Planning of the surgery.

sion, great anatomy deformity). A lot of work should be done, in order to give clear instructions or maybe guidelines regarding the use of navigation and PSI in shoulder arthroplasty. Further controlled long term clinical studies are needed to find a conclusion.

Moreover, computer-aided shoulder navigation is especially useful in situations where normal anatomy is distorted, such as with fractures, revisions, and glenoid wear or dysplasia (8).

Intraoperative navigation with patient specific instrumentation (PSI) improve the surgeon's accuracy. Disadvantages of computer aided surgery are primarily related to the cost of the hardware and software (5). There is also a greater time requirement necessary for training and use of the planning software compared to traditional techniques, as well as the longer execution of the navigated surgery.

Every shoulder arthroplasty requires a unique performance due to patient's unique anatomy of the shoulder. Screw length is important to maximize the bicortical engagement and navigation helps to achieve this in the most adequate way. This might lengthen the stability and longevity of prosthesis. Performance should be different as little as possible from the preoperative plan.

Standard instrumentation (SI) for glenoid positioning in total shoulder arthroplasty is inaccurate. However, the clinical significance of this has not been well established (6). Navigation system and Patient-Specific Instrumentation improve glenoid positioning outcomes, but with significant heterogeneity of results across studies.



Figure 2. Customized JIG.

2. OUR OPERATING TECHNIQUE - NAVIGATION WITH AN INDIVIDUALIZED (PATIENT PLUS PROSTHESIS SPECIFIC) PRINTED JIG

Every navigation starts with an appropriate preoperative planning (Figure 1). Navigation is just a tool for precise execution of our planning. The whole process starts with a Computer Tomography (CT) or CT arthrography. Once we have a CT scan, we perform a 3D reconstruction of the joint.

In case of artefacts produced by a radiographic contrast, those artefacts are removed by a special software, so the bone is extrapolated. Same procedure can be applied in case of CT performed on bone with metal implant. Once we have a 3D model of glenohumeral joint, we firstly calculate the inclination and version of articular surface. Chosen glenoid component is virtually implanted.



Figure 3. While executing the navigation during the surgery.

Once our plan is done, we start with our surgery. After exposure of the bone, we introduce a first probe into it. That probe is connected to the computer. With a second probe, we touch several points on the bone, so that the computer matches the real bone with our 3D plan. Once the matching is achieved, a JIG with the same probe, is used as a guide for pin placement, saw blade or any other device we want to navigate. Looking at the monitor while performing the implantation helps us to follow the preoperative plan. However, we try to be as close as possible to the preoperative plan.

In our technique, a JIG is printed for a single device we want to navigate (Figure 2). In that way, we can create not only a patient-specific navigation, but also a prosthesis-specific navigation. With other words, we use a navigation system, that is a combination of JIG (used as a carrier on one side for a probe and on the other side as a carrier for any instrument we want to use in a specific direction) and classical navigation. That system permits us to navigate everything (Figure 3). We can use it in shoulder arthroplasty for the precise glenoid placement, we can use it in periacetabular osteotomies, osteotomies around the knee, ankle, maxillofacial surgery. The main advantage of our described system comparing to others on the market is that it is not specific for only one company prosthesis instrumentation/devices.

3. DISCUSSION

Learning curve is difficult in life-critical areas (e.g. medicine), where the required level of expertise is high, and students need to spend a considerable amount of time in operation rooms or using training stations (8).

Cadaver practice with NAV and PSI should be prerequisite for performing the surgery on patients. Is it always happening? Human-computer interaction (HCI) is a multidisciplinary field. Additionally, artificial intelligence (AI) is evolving field and present topic in education over the past two decades (9-11).

Intraoperative guidance technology in the form of computer-assisted surgery (navigation) and patient-specific instrumentation allow surgeon to execute the preoperative plan with a greater degree of accuracy and precision and has shown superiority to standard instrumentation (SI) (12).

Heterogeneity is high in studies that include different positioning systems (NAV, PSI and SI). Heterogeneity is due to differences in surgical technique, implants, surgeon's expertise, radiographic image analysis technique. Clinical studies have shown that malposition is common in failed TSA (12), and that malposition is associated with reduced range of motion (13) and increased radiolucent lines (13, 14).

Simply written, critical, future-oriented paper by Porcellini presented up-to-date discussion with precise comments regarding the technology applications in shoulder arthroplasty. Some surgeons, especially experts and skilled ones, will probably consider CAS a waste of time and not necessary. However, similar concerns are usually raised when new technologies are introduced into surgical practice (5).

Alongside the pre-operative and intra-operative assessment, the post-operative follow-up should also be done. On the humeral side, retroversion and the contact point with the glenoid component should be studied for complete navigation in the future; the length and lateral off-set of the humeral component need to be properly planned, to avoid over-tensioning of the plexus, cuff or remaining cuff and deltoid (5).

With prior surgeon training, after 8 operative cases surgeons achieve proficiency in intraoperative computer navigation of the glenoid component, although differences in time are most likely due to individual case complexity. However, the study was supported by Exactech¹ and its products were used in the study, which must be taken into consideration. Moreover, surgeon's previous experience with navigation may shorten the learning curve for navigation in new joint, and this was also presented as one of the limitations of the study (15).

The goal of computer-assisted surgery (navigation) is to increase surgical accuracy and reduce the chance of malposition. Computer-assisted navigation allows surgeons to obtain real-time feedback, while decreasing the potential intraoperative errors, in order to make the adequate prosthesis placement (16).

Future high level studies should give the answer about the use of navigation and PSI, while taking into consideration functional outcome, prosthesis longevity, cost and surgical time. No studies identified in the literature search directly compare NAV to PSI for shoulder arthroplasty (6).

It is impossible to say whether the prosthesis for the determined (single) patient would have better clinical results and prosthesis longevity with or without navigation with PSI - because once the prosthesis is implanted, there is no way back. So, it is impossible to make such studies. Many studies suggest that better imaging results potentially lead to better clinical results and prosthesis longevity.

However, the proposed benefits of the technology applications including improved glenoid survivorship, reduced revision arthroplasty rate and cost-effectiveness have not yet been demonstrated clinically (17). The end point of correction for the glenoid wear in shoulder arthroplasty is controversial, but anatomic glenoid component positioning

¹ Exactech is a company that develops, manufactures, markets and sells the orthopaedic implant devices and related surgical instrumentation

is likely to improve long-term survivorship of the total shoulder arthroplasty (17).

4. CONCLUSION

The use of navigation systems and PSI should be clinically proven in the shoulder arthroplasty. Independent experts' opinion and independent high level studies lack at the moment. There will be still a lot of talk regarding this topic in future.

- **Author's contribution:** D.J. and B.M. gave substantial contributions to the whole work: objective, design and discussion. D.J. did article preparing for drafting and revising it critically for important intellectual content. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
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