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Editorial

Is CT indispensable in shoulder arthroplasty in 2019?

1. Introduction

There was a time, not so long ago, when shoulder replacement could be indicated and carried out without help from cross-sectional imaging such as CT. X-ray sufficed to diagnose osteoarthritis; implantation depended on the surgeon's experience and was adapted according to the morphology encountered; and follow-up was clinical and on plain X-rays.

That era now seems past and gone: the current generation of orthopaedic residents will probably not even be able to imagine it in a few years' time.

In assessment and follow-up, indications for anatomic or reverse arthroplasty are now tailored to glenoid morphology and wear. CT is critical for the preoperative analysis of bone and soft tissue structures governing indications. Implant positioning determines longevity, especially in total anatomic arthroplasty [1] and reverse arthroplasty [2]. CT has become indispensable for preoperative planning, and 3D acquisitions have enabled patient-specific instrumentation and intraoperative navigation to be developed, enhancing precision [3].

Loosening, especially of the glenoid component, used to be overlooked, being relatively asymptomatic; but it is now increasingly important that this should be diagnosed – once again, according to several authors, by CT check-up optimized by digital applications to reduce artifacts [4].

It is particularly important to be aware of these developments and to define the precise field of application of this costly and irradiating examination in shoulder replacement. We therefore reviewed recent publications, notably in *Orthopaedics & Traumatology: Surgery & Research* (OTSR), in quest of determining factors.

2. CT in indications for shoulder arthroplasty

Gilles Walch was the first to stress the need to analyze and classify natural or acquired glenoid morphology before indicating arthroplasty [5]. B2 glenoids in particular have been the subject of much discussion as to choice of type of implant, deformity correction technique and implant survival prognosis [6–8]. Now in 2019, it is no longer conceivable to discuss a shoulder arthroplasty without having a CT scan and the glenoid type on the (recently updated) Walch classification [9]. Type B glenoids are defined by posterior subluxation with more or less severe erosion. Type B3, recently defined, is a progression from the biconcave B2 to a uniconcave form in retroversion with subluxation and medialization of the humeral head [9,10]. Type D corresponds to anteversion exceeding 5° [11]. Like MRI, CT also analyzes fatty infiltration of the rotator cuff muscles, which is a determining factor for indication. These classifications highlight the importance of 3D analysis of the joint deformity, further justifying resort to CT [12].

The classification is important not only in order to anticipate technical difficulties during implantation, but above all for selecting the implant best adapted to the glenoid morphology and, in particular, choosing a reverse prosthesis in case of severely impaired glenoid bone stock, as in types B2 and B3. The use of augmented or compensated implants is also based on morphologic aspect, again justifying resort to a preoperative planning based on CT [13,14].

In case of fracture, fracture sequelae, inflammatory arthropathy or tumor, CT is indispensable for assessment of bone quality, bone defect and rotator cuff muscle status, all of which determine the choice between an anatomic prosthesis (hemiarthroplasty or total shoulder replacement) or a reverse prosthesis.

3. CT in preparing surgery and implant positioning

Many studies have shown that long-term results, complications and risk of loosening correlate with implant positioning. Friedman et al. [15], in a CT study, defined a transverse scapular axis by a line from the mid-point of the glenoid cavity to the medial extremity of the scapula, which is the mechanical axis which has since been the reference for glenoid implantation [12]. Measurements taken on 3D CT acquisitions have been validated [16] and can be automated [17].

Several digitized planning tools have been developed to determine the ideal implant position according to glenoid deformity and Friedman axis [17,18]. Planning also serves to determine the glenoid reconstruction required in severe deformity, with use of grafts, augmented implants or excentric reaming [19–21]. Jacquot et al. [22] demonstrated that the surgeon is able to achieve positioning very close to that established on 3D planning. In the particular cases of extensive glenoid or humeral bone defect, revision surgery or tumor resection, CT is essential for determining the dimensions of patient-specific implants [23,24].

Patient-specific guides were naturally developed to reproduce planning parameters during actual implantation. It is mainly a matter of locating pin entry point and orientation by means of a custom-made template based on the 3D reconstruction and planning data provided by the preoperative CT scan. Many studies have analyzed precision [25–30]. 3D printing is now well established for producing these specific guides, and is also beginning to be used for producing certain implants. It may also have a role to play

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in surgical preparation and simulation, especially when complex bone reconstruction is planned. For teaching purposes, 3D scapular reconstruction based on the patient's CT data can certainly find a useful place between plastic bones and the anatomy lab [31].

Navigation in shoulder arthroplasty was introduced some 10 years ago, using various systems all based on preoperative CT [32–34]. These initial experiences, however, were not pursued, due to the complexity of the systems and excessive technical failures during surgery [32]. Since 2016, navigation has made a comeback, with the introduction of touch-screens and new sensors. Encouraging results have been validated in cadaver studies that should soon be validated clinically [35,36].

In a probably very near future, in the light of recent studies, augmented reality will make CT even more important as a basis for reconstructed images available in real time via connected glasses or a virtual reality mask. The pathologic image will also be enhanced by artificial intelligence using optimal anatomy reference data, providing the surgeon with ever more precise guidance for reconstruction [37,38].

4. CT in postoperative follow-up

CT was long excluded from the postoperative phase, due to metallic artifacts generated by the implant itself which hindered image interpretation, especially for loosening-related radiolucency. To eliminate these, Thomas Gregory first described a protocol for detecting glenoid radiolucencies in lateral decubitus and maximal shoulder flexion [39].

New generation CT scanners now incorporate image processing that reduces or eliminates metallic artifacts [4]. This opens the way for postoperative control of implants, with earlier and higher resolution detection of humeral and above all glenoid radiolucency. It also enables implant-positioning quality to be checked, with more precise screening for the causes of early or later pain following implantation [1,40,41]. Eliminating metallic artifacts also allows analysis of periprosthetic soft tissues: rotator cuff muscle, effusion in case of infection, and recurrence in case of tumor. The postoperative role of CT alongside routine standard radiography needs to be better assessed, considering the cost and the radiation dose to the patient.

5. Conclusion

CT is indispensable preoperatively, for indications and choice of implant. Planning based on 3D reconstruction is becoming equally indispensable. In positioning the implant, guidance systems directly or indirectly based on CT are increasingly used, and the development of these technologies is accelerating, with real-time imaging and image processing by artificial intelligence. CT thus contributes to improving indications and to precision in implant positioning, holding out hope for better clinical results, reduced complications and better long-term implant survival, although all this needs confirmation in clinical studies.

Postoperatively, CT provides far more information than standard X-ray; but should it become a routine examination, and when should it be indicated, considering its higher cost than standard radiography and the non-negligible radiation dose involved?

OTSR and the other specialist journals have a major role to play in objectively analyzing the role of CT at each stage of implementation and follow-up of shoulder arthroplasty, and in assessing the new technologies based on CT imaging which are now on offer to shoulder surgeons.

Disclosure of interest

PH. Flurin is a consultant for Exactech.
F. Sirveaux is a consultant for Wright.

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Pierre-Henri Flurin*
Clinique du sport Bordeaux-Mérignac, 4, rue Georges-Negrevergne, 33700 Mérignac, France

François Sirveaux
Centre chirurgical Emile-Gallé, CHRU de Nancy, 49, rue Hermite, 54000 Nancy, France

* Corresponding author.
E-mail address: phflurin@gmail.com (P.-H. Flurin)