Adult Reconstruction Tips & Tricks: Systematic Approach to THA Templating

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Introduction

Hip arthroplasty has consistently been shown to relieve pain and improve function[1,10]. Advancements in implant design, surgical technique, and anesthesia have increased the reliability of the hip prosthesis and decreased risk of complications. However, hip arthroplasty procedures at times fail[4,8]. These failures can be secondary to excessive wear at certain locations from component position, dislocation, and fixation failure. Mechanical failure is also multi-factorial and dependent on materials, design, position, bone quality, as well as biologic response to wear debris[1,7]. Many of these factors leading to arthroplasty failure are not under the control of the surgeon. Fortunately, thorough preoperative planning may mitigate the likelihood of factors leading to failure.

Total hip arthroplasty templating processors anticipate the size and position of implants prior to surgery. Meticulous planning allows surgeons to anticipate potential difficulties, to reproduce hip biomechanics, to minimize leg length inequalities, and to achieve reproducible results[3,5,9].

The above can be achieved by following a step-by-step approach that encompasses first analyzing the appropriate radiographs, establishing appropriate radiographic and anatomical landmarks, identifying and correcting limb length discrepancy, and lastly templating the acetabulum and the femoral components.

Radiographic Analysis

First and foremost, total hip arthroplasty templating requires standard sets of radiographs. The first image obtained should be a low AP pelvic radiograph with the x-ray beam centered on the pubis. Low AP pelvic films allow the surgeon to visualize the proximal third of the femur and are in approximately the same horizontal plane as the x-ray source. The AP views are obtained with the patient lying supine on the table with the hips internally rotated about 10 to 15° which accounts for normal anteversion of the femoral neck while the neck is parallel to the film. An adequate AP Pelvis XR demonstrates the following findings: the coccyx is roughly 3cm directly superior to the pubic symphysis, the obturator foramina, teardrops, and prominence of the lesser trochanters are symmetric, and the spinous processes are midline.

Figure 1 reveals a helpful demonstration as to the anatomical landmarks that are helpful to define preoperatively to help assist with templating[1]. Important landmarks for the femoral side include the medullary canal, greater and lesser trochanter, as well as the saddle point which is determined by drawing a line that connects the superior portion of the femoral neck with the medial portion of the greater trochanter.

If the radiographs are obtained with the hips overly rotated internally or externally, the true femoral offset and length will be underestimated. Femoral offset is defined as the distance from the femoral head center of rotation to a line bisecting the long axis of the femur. A good method to determine an acceptable amount of internal rotation is to analyze the amount of lesser trochanter shown on imaging. From the medial aspect of the femur, less than 5mm of the lesser trochanter should be visualized.

The surgeon must also know the magnification of the radiograph obtained. The standard magnification is 20%. This can be accomplished when the x-ray tube is 1 m from the tabletop and the film is placed in a tray 5 cm below the table. Magnification markers can also improve precision in templating. Magnification markers consist of a plexiglass tube with two lead spheres embedded at an exact distance of 100 mm.

Placement of the magnification marker can be at two separate locations. First, the marker can be placed at the level of the greater trochanter against the patient's skin. While the second way involves placing the object close to the pubis symphysis between the patient's legs and in the plane of the greater trochanter. However, this location may not be received well by patients and radiology technicians. Notably, placing the marker closer to the pubic symphysis induces less projection errors and thus leads to less magnification errors in clinical practice (2). Increasing the distance between the x ray source and the patient as well as decreasing the distance between the patient and the film will both serve to decrease magnification factor.

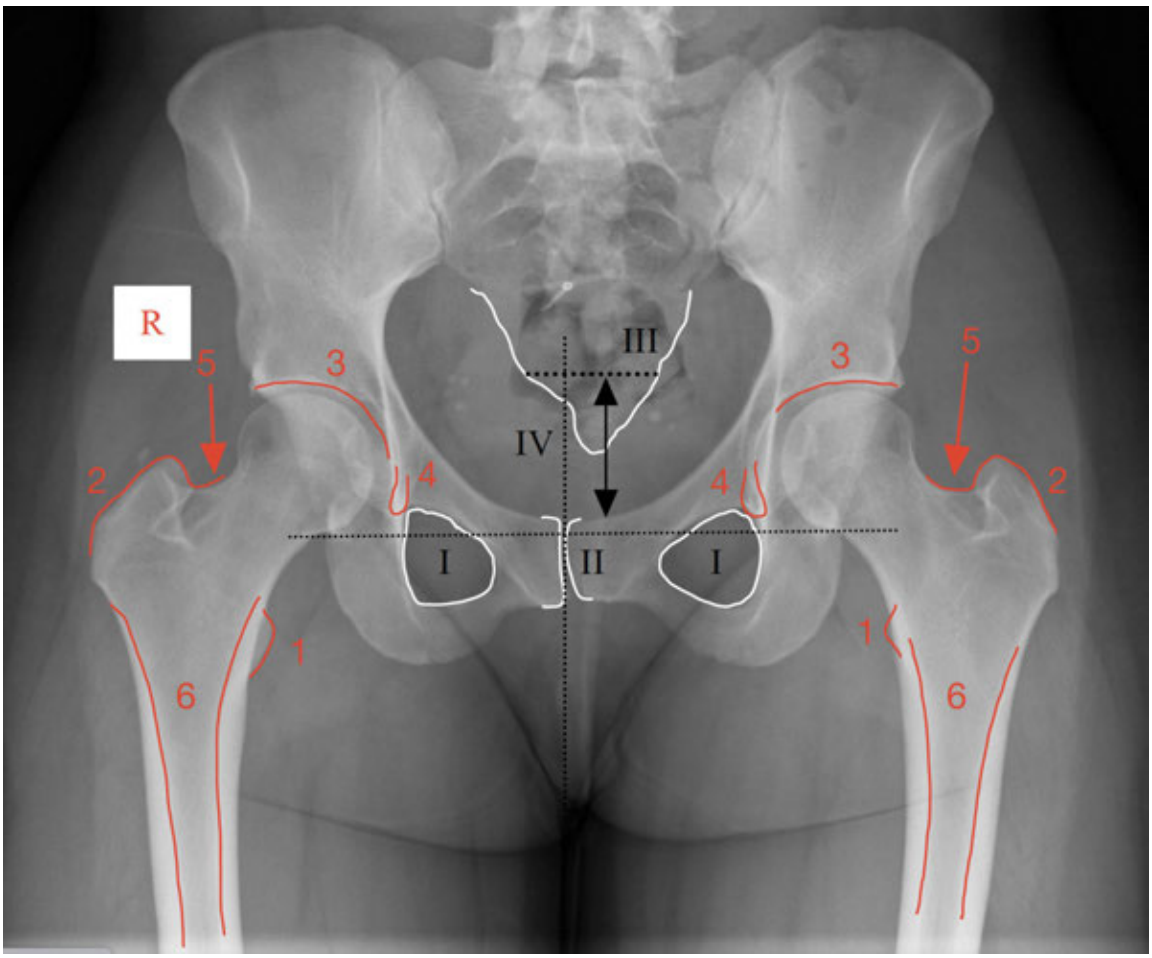

Figure 1. Standing anterior posterior pelvic radiograph for templating the hip. **(A)** Anatomical landmarks: 1. Lesser trochanter; 2. Greater trochanter; 3. Acetabular roof; 4. "Teardrop"; 5. "Saddle"; 6. Femoral shaft. **(B)** Landmarks for assessing radiographic quality: I. Obturator foramen; II. Pubic symphysis; III. Sacrum; IV. Distance between pubic symphysis and sacrococcygeal joint.

THA Templating

Historical perspective

Before computer models for templating for THA became standardized, templating previously occurred with the use of pre-made drawings. In order to perform this, radiographs were printed out with landmarks drawn in by hand. Templates of the acetabular components and femoral components were then physically overlaid beneath the radiographs. Multiple templates of varying sizes could then be used in order to estimate the most appropriate fit. Disadvantages to this method include the amount of time required to template as well as difficulties evaluating the image magnification factor.

General overview

Templating should follow the steps of surgery: acetabular side first, followed by the femoral side. The measured distances and implant sizes should be recorded following a pre-established order so that the surgical team understands and follows the plan throughout the surgery. The first step in templating is to draw a horizontal reference line through the base of both teardrops. These radiographic landmarks are the superposition of the most distal medial wall of the acetabulum and the anterior and posterior horns of the acetabulum[1,6].

The teardrops are the most accurate anatomic landmarks in relation to the bony acetabulum because they are located close to the center of rotation of the hip joints[2,6]. Alternative horizontal reference lines can be drawn through the most distal aspect of the sacroiliac joints and through the most distal aspect of the ischial tuberosities. However, the farther away from the center of the hip joint that anatomic structures lie, the more potential error is introduced by pelvic rotation. Several key radiographic landmarks, which can be visualized during acetabular exposure, should be marked before cup templating: the base of the teardrop, the ilioischial line, and the superolateral margin of the acetabulum[2,6]. The acetabular roof, which bears a significant portion of the body's weight, should also be drawn.

There are a variety of different methods to calculate the limb-length discrepancy both anatomically and radiographically. The actual limb-length discrepancy is determined by measuring the distance between the anterior superior iliac spine and the medial malleolus. The functional limb-length discrepancy is what the patient perceives while in a standing position; it can be determined by placing blocks under the affected side until the patient feels the limbs' length to be "equal"[3].

Another radiographic method on an AP pelvis is to draw a horizontal line that connects the ischial tuberosities taking note to bisect the bilateral medial femoral cortices.

Then, draw a second horizontal line that connects the lesser trochanters at their most proximal aspects. Finally, measure the distance between the lesser intertrochanteric line and the intertuberosity lines. Alternatively, a line connecting the base of the bilateral teardrops can be used instead of the intertuberosity line.

Acetabular Templating

In order to template the acetabulum, first draw a horizontal reference line through the base of the teardrops and identify three anatomic landmarks as stated earlier: the base of the tear drop, the ilioischial line, and the superolateral margin of the acetabulum. Next, an appropriately sized cup is placed in 40 degrees (+/− 10 degrees) of abduction in the frontal plane. The medial portion of the cup should lie near the ilioischial line, and the inferior border of the cup should lie in close proximity to the distal end of the teardrop. Once the template is in an adequate position, mark the acetabular component center of rotation (COR). Next, compare the templated COR to the contralateral center to determine whether they area at the same vertical and horizontal difference from the reference line. The difference may be recorded to compensate for limb-length discrepancies[2].

Furthermore, there are multiple conditions that should be evaluated when templating and the appropriate adjustments should be made pre- and/or intraoperatively. These include but are not limited to the following: 1) In cemented cups, templating should allow for a uniform cement mantle of 2 to 3 mm. If lateral coverage of the cup is incomplete, the uncovered area should be measured and reproduced during surgery. 2) In patients with protrusio acetabuli, care should be taken when reaming to not extend to the full depth of the protruded medial wall and to consider bone graft to fill the defect. Proper placement of the cup improves soft-tissue tension and decreases the possibility of impingement. 3) Patients with a lateralized acetabulum secondary to medial osteophytes will also require attentive reaming to ensure that the acetabulum is reamed until the ligamentum teres, pulvinar, cotyloid notch and transverse acetabular ligament are visualized. Failure to remove the medial osteophyte can lead to a lateralized cup resulting in suboptimal fixation and insufficient coverage.

Femoral Templating

In order to template the femur, choose a femoral implant that approximates the size of the medullary canal. Take note of the potential use of cement for the femoral component as this may impact the size of the stem. Also note the potential insertion depth of the femoral component to address any potential leg length discrepancies. Pre-operatively mark the femoral intended femoral neck resection level as well as the femoral head center of rotation.

Relative superior/inferior placement of the COR between the acetabulum and the femur can impact the limb lengths. If the acetabular COR is superior to the femoral COR, the limb will be shortened. Conversely, if the acetabular COR is inferior to the femoral COR, the limb will be lengthened.

Relative medial/lateral placement of the center of rotation (COR) between the acetabulum and the femur can impact the offset. If the acetabular COR is medial to the femoral COR, the offset will be decreased. If the acetabular COR is lateral to the femoral COR, the offset will be increased. Offset can also be modified by altering the length of the femoral neck, selecting stems with varying neck shaft angles, as well as choosing a stem with more or less offset.

Conclusion

Preoperative planning is essential to total hip arthroplasty. Templating allows assessing the relation of the different anatomical and radiographic landmarks to anticipate difficulties prior to surgery. However, it might be difficult if not done in a systematic approach. Consistently performing THA templating and reproducing the situation combined with the appropriate surgical implantation and techniques should help the surgeon reduce the number of potential complications and help perform the procedure expediently.

References:

1. Scheerlinck T. Primary hip arthroplasty templating on standard radiographs. A stepwise approach. *Acta Orthop Belg.* 2010;76(4):432-442.

2. Della Valle AG, Padgett DE, Salvati EA. Preoperative planning for primary total hip arthroplasty. *J Am Acad Orthop Surg.* 2005;13(7):455-462. doi:10.5435/00124635-200511000-00005

3. Vigdorchik JM, Sharma AK, Jerabek SA, Mayman DJ, Sculco PK. Templating for Total Hip Arthroplasty in the Modern Age [published correction appears in J Am Acad Orthop Surg. 2021 Jul 1;29(13):e655]. *J Am Acad Orthop Surg.* 2021;29(5):e208-e216. doi:10.5435/JAAOS-D-20-00693

4. Scheerlinck T, De Winter E, Sas A, Kolk S, Van Gompel G, Vandemeulebroucke J. Hip implants can restore anatomical and medialized rotation centres in most cases : a 3D templating study comparing four implantation strategies. *Bone Jt Open.* 2021;2(7):476-485. doi:10.1302/2633-1462.27.BJO-2021-0065.R1.

5. Hasler J, Hoch A, Fürnstahl P, Ackermann J, Zingg PO, Vlachopoulos L. Is the contralateral lesser trochanter a reliable reference for planning of total hip arthroplasty - a 3-dimensional analysis. *BMC Musculoskelet Disord.* 2021;22(1):268.

6. Colombi A, Schena D, Castelli CC. Total hip arthroplasty planning. *EFORT Open Rev.* 2019;4(11):626-632. Published 2019 Nov 1. doi:10.1302/2058-5241.4.180075.

7. Sahemey R, Moores TS, Meacher H, Youssef B, Khan S, Evans CR. Anthropometric method for estimating component sizes in total hip arthroplasty. *World J Orthop.* 2021;12(11):859-866. Published 2021 Nov 18. doi:10.5312/wjo.v12.i11.859.

8. Haddad FS, Masri BA, Garbuz DS, Duncan CP. The prevention of periprosthetic fractures in total hip and knee arthroplasty. *Orthop Clin North Am.* 1999;30(2):191-207.

9. Crooijmans HJ, Laumen AM, van Pul C, van Mourik JB. A new digital preoperative planning method for total hip arthroplasties. *Clin Orthop Relat Res.* 2009;467(4):909-916. doi:10.1007/s11999-008-0486-y.

10. Bishi H, Smith JBV, Asopa V, Field RE, Wang C, Sochart DH. Comparison of the accuracy of 2D and 3D templating methods for planning primary total hip replacement: a systematic review and meta-analysis. *EFORT Open Rev.* 2022;7(1):70-83. Published 2022 Jan 11. doi:10.1530/EOR-21-0060.