Clinics in Surgery

Research Article
Published: 25 Oct, 2021

The Role of Routine Post-Operative Computed Tomography in Acetabular Fracture Fixation

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Abstract

Aim: Acetabular fractures commonly occur following road traffic accidents or falls from height. Peri-operative fluoroscopy may be an insufficient tool in assessing them and routine post-operative CT imaging following fixation remains controversial. The purpose of this study was to evaluate the role of post-operative CT imaging in the management of acetabular fracture fixation.

Methods: Retrospective analysis of a prospectively collected database from November 2009 to December 2019 yielded 121 patients in a single centre.

Results: The mean age at injury of the cohort was 37.6 years old (range 13 to 73). There were significant differences between the two modalities used ($p<0.001$) and 10 patients (8.3%) required conversion to a THA. The mean re-operation time was 24.5 months (range 1 to 65 months). Significant association was seen between worse post-operative CT scan grade and further surgery ($p<0.001$). Similarly, a significant association was identified between worse post-operative radiograph grade and further surgery ($p<0.001$).

Conclusion: CT imaging provides a lot more information over post-operative radiographs. Worse grades of fracture reduction in CT scan and post-operative radiograph are associated with re-operation. THA is decided on clinical findings and performed to alleviate post-operative arthritis, not to treat radiological grading. Furthermore, it can be used as a training tool for teaching purposes.

Keywords: Computed tomography; Acetabulum; Fracture

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Received Date: *23 Aug 2021*
Accepted Date*: 13 Oct 2021*
Published Date*: 25 Oct 2021*

Citation:
Orfanos G, Goh EL, Dwyer J, Lim J, Youssef B. The Role of Routine Post-Operative Computed Tomography in Acetabular Fracture Fixation. Clin Surg. 2021; 6: 3337.

Introduction

Acetabular fractures commonly occur following road traffic accidents or falls from height [1]. Peri-operative fluoroscopy cannot always assess the accuracy of the reduction, the presence of retained osteochondral fragments and intra-articular screw penetration [2,3]. These could lead to pre-mature post-traumatic arthritis. Historically, post-operative radiographs have been used to identify these factors, thus enabling revision surgery where necessary [4]. Post-operative Computed Tomography (CT) may be advantageous in this setting due to the potential of this imaging modality to identify correctible factors that are not apparent on peri-operative fluoroscopy and post-operative radiographs [5]. The role of routine post-operative CT imaging following acetabular fracture fixation remains controversial. Previous studies have suggested that the benefits of this approach are restricted to a small proportion of patients [6,7]. Furthermore, there are risks associated with additional radiation exposure to the patient as well as healthcare expenditure [8]. Recent works on this topic have suggested that post-operative CT imaging provides valuable information for prognostic and quality assurance purposes. Given the lack of clarity as to which patients are likely to benefit from this, it is evident that further research is required [6,7]. The present study aims to evaluate the role of post-operative CT imaging in the management of acetabular fracture fixation.

Methods

Study population

In our Level 1 trauma centre, a prospectively kept database is filled in with any pelvic and acetabular fracture, since 2006. A retrospective search was performed to identify only acetabular fractures that have had an open reduction, internal fixation as a primary form of treatment. Patients having fixation and Total Hip Arthroplasty (THA) at the same admission were excluded. Patients with missing fluoroscopic images, or CT scans were also excluded. Out of the initial 164 patients identified in our databases, only 121 were eligible, from November 2009 to December 2019. Basic demographic and surgical characteristics were noted. The acetabular fracture pattern was classified according to Letournel and Judet classification [9].

Study protocol

Each patient had peri-operative fluoroscopy to assess the quality of the reduction and to check the implant position was satisfactory. An immediate CT scan forms part of our post-operative protocol. Furthermore a post-operative plain film radiograph is taken at 6 weeks follow up.

Data assessment

Radiographs were categorized as 'safe', if there was no suspicion of metalwork malposition, intra-articular penetration or fragment retention; 'inconclusive', if malposition or intra-articular fragment cannot be excluded; 'definite' malposition, if there was definitive metalwork malposition or retained fracture fragment, based on the classification system described by Elnahal et al. [7]. The findings were compared with the intra- and post-operative plain film radiographs. Metalwork malposition was defined as screws protruding more than 10 mm into soft tissue or intra-articular penetration of the acetabulum. Those CT scans were assessed (1 mm or 2 mm slice thickness) in coronal and sagittal views and graded in the same aspect. The Matta criteria were used to assess the quality of reduction in the post-operative CT scan and plain radiographs, grading them as anatomic (0 mm to 1 mm displacement), imperfect (2 mm to 3 mm displacement), or poor (more than 3 mm displacement) [10]. The articular surface gap and step measurements were measured using a standardized measurement technique [11,12]. The quality of fracture reduction in postoperative CT scan was reviewed using a similar technique as described by Verbeek et al. [6]. The biggest gap or step was measured on the axial, coronal and sagittal views and the location was noted (anterior wall, anterior column, dome, posterior wall, posterior column). The vertical distance from the most proximal level of the weight bearing dome was noted. Verbeek et al. [13] defined the weight bearing dome as the area of subchondral bone or arc in the proximal 10 mm vertical height. The quality of reduction was graded as anatomic, imperfect or poor based on the maximum gap or step measurement on the CT scan and compared to plain radiographs.

Statistical analysis

IBM SPSS Statistics version 23 (Armonk, New York) was used for data analysis. Descriptive statistics were used to identify correlation. Categorical data were compared using the χ^2 test and Fisher's exact test for low numbers. A p-value <0.05 was considered to be statistically significant.

Ethics approval

This was a retrospective study and only anonymised data previously acquired as part of the patient workup or for service evaluation purposes were used. Ethical approval was waived following review of the study proposal by the local ethics committee.

Results

The mean age at injury of the cohort was 37.6 years old (range 13 to 73). There were 96 (79.3%) male and 25 (20.7%) female. There were 62 (51.2%) left acetabular fractures and 59 (48.8%) right acetabular fractures. The mode of trauma was caused by road traffic accidents (62.8%), fall from height (18.2%), and sports injury such as rugby or horse riding (9.1%), farming injury (7.4%) and other modalities (2.5%). The majority of fracture types were posterior wall with transverse wall (22.3%), followed by posterior wall (21.5%). Table 1 outlines each classification according to Letournel and Judet classification [9]. The mean time to theatre was 5 days (range 0 to 17 days). After review of the peri-operative fluoroscopy images and post-operative plain radiographs, 96 (79.3%) patients were categorized into the 'safe group', 23 (19.0%) patients into the 'inconclusive' group and one (0.8%) into the 'definitive malposition' group. All patients were noted to have satisfactory metalwork placement, and there was no intra-articular metalwork present on the post-operative CT scans. The acetabular fractures were graded as anatomic, imperfect or poor based on the quality of the reduction on the post-operative CT scan and plain film radiographs. Table 2 shows that there were significant differences between the two modalities (p<0.001). The table included 117 patients out of the 121, due to four missing their postoperative plain film radiograph. There were 90 out of 117 (76.9%) found to be anatomic on plain film radiograph, but only 63 out of 117 (53.8%) were anatomic on CT scan. Of the 90 graded anatomic on the plain film; 63 were graded anatomic, 24 imperfect and three poor on CT scan. Similarly, there were 18 out of 117 (15.4%) with an imperfect reduction on plain film radiograph and 31 out of 117 (26.5%) with an imperfect reduction on CT scan. Finally, poor reduction was documented in nine out of 117 (7.7%) on plain film radiograph, but 23 out 117 (19.7%) on CT scan. Using plain film radiographs, the mean fracture displacement measurement was 1.2 mm (range 0 mm to 9 mm). Using CT, the mean fracture measurement was 2.4 mm (range 0 mm to 14.4 mm). There were 74 (61.2%) patients with fractures extending within the dome region and 47 (38.8%) below the dome, in CT measurements. The location of the widest gap or step, was 72 (59.5%) in the posterior wall, 23 (19.0%) in the anterior column, 11 (9.1%) in the posterior column, 8 (6.6%) in the transverse wall and 7 (5.8%) in the anterior wall. There was no significant association between fracture pattern and CT scan reduction grade (p=0.346). Ten

Table 1: Classification of acetabular fractures.

Fracture Type	Number	Percentage (%)
Transverse + Posterior wall	27	22.3
Posterior wall	26	21.5
Associated both columns	20	16.5
Posterior wall + posterior column	16	13.2
T-type	13	10.7
Anterior column	7	5.8
Posterior column	5	4.1
Transverse	5	4.1
Anterior column posterior hemitransverse	2	1.7
Total	**121**	**100**

Table 2: Accuracy of plain film radiographs and CT scan for quality of reduction.

	CT scan Grade			
	Anatomic	**Imperfect**	**Poor**	**P-value**
Plain Radiograph Grade				
Anatomic	63	24	3	<0.001
Imperfect	0	7	11	
Poor	0	0	9	

patients (8.3%) required conversion to a THA and it was to alleviate symptoms of post-traumatic arthritis. The mean re-operation time was 24.5 months (range 1 to 65 months). Only one patient required an acute revision, due to dislocation during the rehabilitation period. There was significant association between post-operative CT scan grade and further surgery ($p<0.001$), with nine cases being of the poor grade and one being of the imperfect grade. Similarly, a significant association was identified between post-operative radiograph grade and further surgery ($p<0.001$), with three being of the poor grade, six of the imperfect grade and one of the anatomic grade. There was no significant association between further surgery and dome location ($p=0.202$, Fisher's exact test).

Discussion

In the present study, post-operative CT imaging provided more accurate and detailed information on metalwork malposition and the quality of fracture reduction compared to peri-operative fluoroscopy and post-operative radiographs, which corroborate earlier work on this topic [6,8,12-16]. None of the patients in our study required revision surgery for metalwork malpositioning or poor quality fracture reduction, which is consistent with currently published data. However, one patient underwent revision surgery for a THA within two weeks post-operatively due to a fall on the ward and subsequent failure of metalwork with hip dislocation. The remaining nine patients underwent conversions to THA to alleviate symptoms of post-traumatic osteoarthritis. Elnahal et al. reported the accuracy of plain radiographs to be 94%, which is comparable to the present cohort [7]. Furthermore, the authors proposed that although post-operative CT imaging is useful for prognostic and quality assurance purposes, the information obtained rarely influenced management decisions regarding re-operation. In contrast, poor post-operative CT scan grades were significantly associated with further surgery in our study. It has been previously suggested that the use of spring plates is associated with a higher risk of metalwork malposition. This is not supported by our data, where spring plates were utilized in 37 (30.6%) patients in our cohort, without any metalwork malpositioning. A key consideration with CT imaging is the additional radiation exposure, due to cancer-related mortality [17]. This is of particular importance in a cohort such as ours with relatively young patients who have undergone prior radiological assessment as part of the initial trauma work-up and intra-operative fracture fixation. The doses of radiation for a plain radiograph series (three to five views) of the pelvis, low dose CT scan of the pelvis and standard CT scan of the pelvis are 0.32 mSV, 0.79 mSV and 3.5 mSV, respectively [8,18]. Quantifying this further, the equivalent periods of natural background radiation for each imaging modality are two, four and twenty months, respectively [19]. Pertinently, the difference in lifetime additional risk of fatal cancer following a low dose CT is approximately doubles that of a plain radiograph series. With advances in imaging technology over time, the doses of radiation delivered by CT scans and plain radiographs have decreased [18,19]. Herein lies a potential advantage of low dose CT scans. Although these are associated with poorer image quality and increased metal artifacts, the Three-Dimensional (3D) reproduction capability confers advantages in evaluating joint congruence, metalwork position and the presence of soft tissue or visceral injury [20]. It is therefore possible that low dose CT scans of the pelvis may provide the optimal balance between the risks associated with excess radiation and missed complications. Whether the morbidity and mortality due to imaging outweighs that of missed complications is controversial, and cannot be measured objectively. The undoubtable benefit of the post-operative CT imaging for acetabular fractures is its role in surgeon feedback and teaching. This is particularly important to the senior trainee or fellow embarking on a career in pelvic and acetabular reconstruction, but also to the consultant early on in their careers and even for the experienced surgeons where difficulties have been encountered intra-operatively. It is an excellent tool to use for a post-operative analysis of the operation where the imaging can be reviewed in depth and the complex parts of the operation be broken down and explained. Likewise, any technical difficulties encountered intra-operatively are often identifiable on the post-operative CT and reviewing these images as a group of surgeons is extremely valuable in an attempt to identify strategies that could have obtained a better result. The future may involve 3D reconstructions of the CT images, which can be readily incorporated into virtual reality models for use in surgical simulation [21]. Given the complexity of these fractures, simulation plays an important role as an adjunct for surgical trainees to better understand the fracture configuration, generate a pre-operative plan as well as stimulate fracture reduction and fixation [22].

Limitations

Several limitations that must be considered in this study. The retrospective nature of the study has inherent biases and confounding factors that could potentially influence the results. The sample size of our study was restricted to 121 patients, and there was no a priori estimate of sample size. It is possible that the conclusions may change with a larger sample size. Due to the lack of long-term clinical or functional data available, we were unable to correlate the quality of fracture fixation with these. This is because our database does not routinely store functional outcome data obtained during clinical reviews.

Conclusion

In the present study, the information provided from routine post-operative CT imaging conferred additional value over post-operative radiographs in terms of being more detailed. Both worse CT scan and post-operative radiograph grades are associated with re-operation. Although, conversion to THA was performed to alleviate symptoms of postoperative arthritis and not to treat radiological grading. Furthermore, there is potential for CT scans to be used as a training tool for teaching purposes. Our findings therefore advocate for a post-operative CT imaging, in cases that further information is needed, or the patient is symptomatic. Further prospective studies evaluating functional outcomes following acetabular fracture fixation are required to further understand the clinical course of these patients.

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