This article has been accepted for publication in BJOPHTHALMOL following peer review.
The definitive copyedited, typeset version is available online at
10.1136/bjo-2025-327387

The use of pre-operative imaging in open globe injury management: a systematic review

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Funding statement: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing Interests Statement: The authors declare no conflicts of interest regarding this manuscript

Contributorship Statement: JM wrote the report. JM and LB performed paper screening, data extraction, and risk of bias assessment. RB designed the study, performed searches, paper screening, and edited the report. All other named authors - Sophia Halliday[3], David McMaster[4], Edward Sellon[5], Marcus Colyer[6], Scott F McClellan[7], Grant A Justin[6], Annette K. Hoskin[8,9], Kara Cavuoto[10], James Leong[11], Andrés Rousselot[12], Fasika A Woreta[13], Kyle E Miller[6,14], William G Gensheimer[15,16], Thomas H Williamson[17, 18], Felipe Dhawahir-Scala[19], Peter Shah[20,21], Gangadhara Sundar[22], Robert A Mazzoli[6], Ferenc Kuhn[23,24], Malcolm Woodcock[25], Stephanie Watson[11], Renata SM Gomes[3,26], Rupesh Agrawal[27, 28, 29, 30], Richard J Blanch[4,21,31] contributed to study design, editing the report and suggested edits and formed the expert group responsible for initiating and overseeing the study.

Ethics: Not applicable

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Word Count 2908

SYNOPSIS

CT has limited sensitivity for OGI detection of 74% compared to clinical diagnosis. A negative CT does not exclude an IOFB.

ABSTRACT

Importance: Primary repair of open globe injury (OGI) is typically undertaken urgently. Imaging plays an important role in the pre-operative assessment including detection of an OGI and presence of an intraocular foreign body (IOFB). Evidence is lacking on the utility of pre-operative imaging in diagnosing OGI and IOFB.

Objective: The primary objective is to assess the role of pre-operative imaging in OGI. Studies including patients who had sustained an OGI and reporting the findings of radiologic imaging in pre-operative assessment of OGI were eligible for inclusion.

Data Sources: A systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement, searching the Cochrane Central Register of Controlled Trials, PubMed, Medline and ClinicalTrials.gov.

Study Selection: Prospective and retrospective studies reporting pre-operative imaging assessment after open-globe injury were included with no restriction on language or start date up until 15 Dec 2023.

Data Extraction and Synthesis: Eleven studies, ten retrospective and one prospective, with a total of 1126 patients were included, of which nine assessed computed tomography (CT) detection of OGI and three assessed ultrasound for the detection of IOFB. Risk of bias was assessed using the QUADAS-2 tool.

Main Outcomes and Measure: Sensitivity of CT detection for OGI compared to clinical examination by an ophthalmologist and IOFB detection using intraoperative examination findings as gold standard. Pre-operative B Scan ultrasonography (US) sensitivity for IOFB detection compared to CT.

Results: CT was 74% sensitive (95% CI 66.4-80.0) and 93% specific (95% CI 88.2-95.4) in OGI detection compared to clinical diagnosis. CT findings associated with OGI included scleral deformity, altered AC depth, lens abnormality, and vitreous haemorrhage. CT was 69% sensitive (95% CI 51.4% to 82.0%) for IOFB detection using intraoperative examination findings as the gold standard.

Pre-operative B Scan US was not examined for OGI detection but had 86% sensitivity for IOFB detection (95% CI 77-92) compared to the gold standard of CT, but safety with respect to pressure on the globe extruding intraocular contents was not studied.

Conclusions and Relevance: CT had moderate sensitivity but high specificity for OGI detection, and therefore cannot replace clinical assessment by an ophthalmologist. A negative CT does not exclude an IOFB.

Key Messages

What is already known on this topic

Evidence on the sensitivity and specificity of pre-operative imaging to diagnose OGI and IOFB has not been previously compiled.

What this study adds

CT had moderate sensitivity but high specificity for both OGI and IOFB detection. A negative CT does not exclude an IOFB.

How this study might affect research, practice or policy

Imaging cannot replace clinical assessment by an ophthalmologist for IOFB and OGI.

INTRODUCTION

Open globe injuries (OGI) are any injuries with full-thickness defects of the eye wall[1]. OGI are ophthalmic emergencies and a common cause of preventable unilateral blindness worldwide, with an estimated yearly incidence of 4.49 per 100,000 people in the US[2].

Radiologic imaging is a key diagnostic tool in OGI management, particularly where ophthalmic examination is limited, and intraocular foreign bodies (IOFB) and facial and orbital fractures are suspected. Imaging may be particularly important in unconscious patients unable to communicate their eye injury, eyes with opaque media, and patients with extensive peri-orbital swelling that limits examination, and paediatric patients who may be difficult to examine[3]. Further, mid-facial trauma has been associated with an increased risk of globe trauma, which maybe missed during management of multi-system trauma[3,1].

Non-contrast computed tomography (CT) is routinely performed for OGI evaluation and IOFB diagnosis[4] . In polytrauma, most institutions will perform a Whole Body CT protocol, including an unenhanced skull at 120 kV, with 0.6 mm slice thickness, usually reported by on-call radiologists, although ideally also read by the primary service and ophthalmologist managing the patient. CT may detect changes in globe contour, lens abnormality, vitreous haemorrhage, retinal detachment, orbital and facial fractures, and obvious orbital volume loss[5]. CT is useful if a radiopaque IOFB is suspected[6].

IOFB detection using B-scan ultrasonography allows posterior segment examination and may be useful when fundoscopy is restricted by media opacity. A B-scan after OGI may extrude ocular contents by applying globe pressure, and therefore is not usually recommended before repair. Widely adopted protocols for OGI management are lacking. Understanding the evidence on the role of imaging modalities in OGI may help inform guideline development for OGI management.

To provide evidence on the utility of ocular imaging in the management of OGI and IOFB, we performed a systematic review to evaluate the sensitivity and specificity of pre-operative imaging for OGI diagnosis and IOFB detection. A secondary aim was to describe which imaging features and in what combination were most sensitive for OGI detection.

METHODS

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement[7]. Searches were conducted in June 2023 and updated on 15 Dec 2023, including studies since database inception.

Inclusion criteria

Studies including patients who had sustained an OGI (defined by Kuhn[1]) and reporting pre-operative radiologic imaging findings in were eligible for inclusion. Prospective and retrospective studies published in indexed medical journals were included (conference abstracts were excluded). No limitation was placed on language, geographical area of origin or publication date. Studies reporting fewer than 5 patients were excluded to minimize selection bias.

Search strategy

Databases searched included Embase, CENTRAL, Clinicaltrials.gov, and Medline. Search strings are given in Supplementary information – Appendix 1. Records retrieved from database searches were compiled in Endnote and Rayyan[8], and duplicates removed. Titles and abstracts of studies were reviewed by three independent reviewers (SRH, RJB and LB). Disagreements between reviewers on papers' eligibility were resolved by discussion, or arbitration by the senior author (RJB).

Outcomes

Quantitative analysis was performed on the last reported outcomes. The primary outcomes were sensitivity and specificity for OGI detection. Secondary outcomes were sensitivity and specificity for IOFB detection and CT findings in open and closed globe injury.

Data collection and risk of bias assessment

Three review authors (JM, SRH and LB) independently collected data with standardized data collection forms. Individual participant data were extracted where possible. When studies included only a subset of relevant participants, we included only the eligible participants. We made email requests for any missing data from primary investigators. One month was allowed for the authors to respond, and if no response was provided, the review was conducted based on the available information.

Variables extracted were: study information (first author, publication year, study design, and country of origin), participant information (total patients, type of injury reported), population demographics, imaging modality and protocol, sensitivity, and specificity.

Risk of bias was assessed using the Quality Assessment Tool for Diagnostic Accuracy Studies -2 (QUADAS-2)[9]. Level of evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) framework used to present summaries of evidence and provide a systematic approach to making clinical practice recommendations[10].

Statistical methods

A bivariate random-effects model was fitted to summarize sensitivity and specificity,[11] as the study methodologies were highly heterogenous. Meta-analyses were performed using the Meta-Analysis of Diagnostic Accuracy (mada) package in R[12].· Review Manager 5 produced forest plots[13]. Where results were reported for more than one observer without overall estimate of sensitivity and specificity average values were calculated across observers for true positive, false positive, true negative, false negative, rounded to integers and plotted in forest plots.

Studies were pooled for meta-analysis and a summary incidence rate with 95% confidence intervals (CIs) given for primary outcomes. Heterogeneity between studies was assessed using summary receiver operating characteristic (SROC) curves[14].

RESULTS

Searches identified 1794 titles and abstracts with 11 studies meeting the inclusion criteria (PRISMA flow diagram Figure 1). including 1126 patients across 11 studies from five countries: eight of CT detection of OGI and three of ultrasound IOFB detection (Table 1).

<Figure 1>

CT in OGI detection

CT sensitivity in OGI detection included 827 participants (830 eyes) across 8 studies, using clinical diagnosis as gold standard. The meta-analyzed model-derived sensitivity was 74% (95% CI 66.4% to 80.0%; Figure 2a) and specificity was 95.0% (95% CI 88.2% to 95.4%). Heterogeneity, assessed by I^2, was 17.4%. A SROC plot showing approximation to the line of best fit is shown in Supplementary information.

All studies had a sensitivity higher than 71% for OGI CT detection, except one outlier with 51% sensitivity[15], and specificity of at least 79% for OGI detection.

<Figure 2>

CT in IOFB detection

CT sensitivity in IOFB detection included 294 participants across 3 studies, using pre and intraoperative findings as a gold standard[15–17,]. The meta-analysed model-derived sensitivity was 69% (95% CI 51.4% to 82.0%; Figure 2b). Yuan et al.[17] reported 64% sensitivity and 99% specificity and Gad et al.[16] reported 68.4% and 100% respectively. Crowell et al.[15] only had one study participant with an IOFB, while Arey et al.[18] did not report sensitivity or specificity. The SROC plot is shown in Supplementary Information.

US in IOFB detection

No studies analysing US in OGI detection were found. US in IOFB detection included 92 participants across 3 studies. The meta-analysed, model-derived, sensitivity was 86% (95% CI 77-92; Figure 2c) for IOFB detection compared to a gold standard of CT. It was not possible to calculate specificity, as there were no true negatives.

CT findings suggestive of OGI

Four studies commented on the CT findings between open and intact globes (Table 2)[19,18,15,20], including 361 OGI. The CT finding most suggestive of OGI was scleral deformity, in 74% of eyes with OGI. Other suggestive findings included altered AC depth, lens abnormality and vitreous haemorrhage.

Chou et al.[21], evaluated the association of globe ruptures with orbital wall fractures, finding that lateral wall fracture had the highest relative risk 2.286 (95% CI: 1.062-4.919).

Risk of bias

Risk of bias is summarized in Supplementary Information and certainty of the body of evidence is assessed on the basis of risk of bias in Table 3. All studies investigating the use of CT for OGI detection were retrospective, meaning there was a high risk of bias in patient selection. No study commented on the training level or the number of different radiographers involved in conducting the CT scans.

Reference standard: Across all studies of OGI detection, the reference standard used was clinical diagnosis. Seven studies included diagnostic information from both initial examination and surgical exploration but did not specify the level of training of those assessing[17,18,19,20,22,23,24]. Four studies specified that a trained ophthalmology resident conducted the initial ophthalmic examination[15,16,21,23].

Index test CT: Three studies did not state the CT imaging protocol used in IOFB detection[16,18,21]. The studies by Arabi et al.[19], Crowell et al.[15], Hoffstetter et al.[25], Joseph et al.[20], Yuan et al.[17] all reported limited information on CT protocols.

Index test US: Two studies stated the machine used to perform the ocular sonography and the protocol followed[23,24]; however, conducting and interpretating ocular sonography is user-dependent. Farvadin et al.[23], commented that a “skilled ocular sonologist” performed imaging, although did not detail qualifications or experience, while McNicholas et al.[24], and Patel et al.[22], did not report who performed the imaging.

Flow and timing: Arabi et al.[19] and Yuan et al.[17], were the only studies to specify inclusion of patients who had CT's conducted within 24 hours and 6 hours of injury respectively. No study specified how soon after injury ophthalmic assessment was conducted.

Study observers: Most studies using CT as the index test used masked observers except Hoffstetter et al.[25], who combined the original reported data alongside the reports from 3 masked observers, but did not report who the original observer had been. Joseph et al.[20] did not report the specialty of the observers interpreting the CT imaging whilst the remainder used a combination of neuro-radiologists, radiologists and ophthalmologists. Arabi et al.[19], and Crowell et al.[15], analysed the accuracy and agreement between the different readers.

Patient characteristics: Patient characteristics were not reported in all the studies. Two studies only included adults, three studies did not report ages and four included children, the youngest aged two.[15]

Masking of assessments: No included study masked the sonographer to any clinical details. Hoffstetter et al.[25], masked 3 observers but combined the original observer who would not have been masked to the clinical history. The remaining seven studies masked those interpreting the CT imaging to the clinical information [15–21].

DISCUSSION

This systematic review reports data from eleven studies including 1126 patients, finding that pre-operative CT had a pooled sensitivity across eight included studies of 74% and a specificity of 95% for OGI detection and a pooled sensitivity across three studies of 69% for IOFB detection. Ultrasound had a pooled sensitivity across three studies of 86% compared to CT for IOFB detection. The certainty of evidence was low to very low because of retrospective study design, unmasked assessors and heterogeneity and uncertainty in imaging protocols. Although the sensitivity of CT was moderate and specificity was high in the detection of OGI, it did not detect all cases. . In addition, neither CT nor ultrasound had a high sensitivity for IOFB detection, suggesting that imaging tests are useful to rule-in but not rule-out OGI and IOFB.

Three included studies used clinical diagnosis as a gold standard for IOFB detection[15–17], finding a sensitivity of 69% (95% CI 51.4 – 82.0) and a specificity of 99.1% (95% CI 96.4-99.8). Another study looking at the IOFB detection in enucleated eyes, found that spiral CT had a 100% sensitivity for detection of 0.5 mm IOFB of metal, stone or glass[26]. The lower real-world performance in IOFB detection of 69% compared to the laboratory studies probably reflects the difficulty of clinical decision-making, differing slice thickness and the potential for other anatomical, abnormalities, such as intraocular haemorrhage masking an IOFB, to generate confusion. Despite this low sensitivity, CT detected IOFB that ultrasound missed, even with unmasked ultrasonographers, although the reverse comparison was not done (CT being the gold standard). Further, the safety of pre-operative ultrasound, which may extrude ocular contents by pressure on the globe was not considered.

The relatively low real-world sensitivity of CT in IOFB detection (69%) is an important finding. Clinicians should be aware that a negative CT does not exclude the presence of IOFB, and, when suspected, repeat imaging with high resolution CT scan, or magnetic resonance imaging (MRI) when organic material is suspected, may be indicated after primary globe repair.

A gentle post-operative ultrasound examination by the treating ophthalmologist may also be considered when the clinical suspicion of IOFB remains high, although evidence does not suggest ultrasound is able to detect IOFB that CT misses, because studies have not been designed to test this question.

CT may highlight clinically occult OGI; however, no paper distinguished between clinically occult and clinically obvious OGI. Clinical assessment of globe disruption can be difficult and may be challenging when patients are distressed or uncooperative, have altered level of consciousness and significant associated injuries and in these circumstances, CT may be better able to assess an awake patient than physical examination. Not all included studies specified what grade and specialism of doctor conducted the initial assessments, although most studies had an ophthalmologist performing the examination. However, as clinical diagnosis was used as the gold standard, the uncertainty of the expertise of the examining ophthalmologist introduces a degree of uncertainty in the reliability of the initial findings, which may be mitigated by likely senior supervision of doctors in training.

Ideally all studies would have masked the CT observers (although in real-world application, the reporting radiologist is not masked to clinical details), although Hoffstetter et al[25] studies used the initial (unmasked) report. The included studies used a combination of radiologist, neuroradiologist and ophthalmologist, but there were not enough data available to compare performance between specialties in CT interpretation. In the case of ultrasound, a sonographer or doctor typically interprets and reports their findings as they conduct the imaging and masking is thus difficult. CTs would usually be reported by an on-call radiologist of any subspeciality. Although a neuroradiologist may potentially be more accurate in their reporting, subspecialist reporting may not be possible for those conducted out of hours or in a polytrauma setting.

Study heterogeneity is usually higher between diagnostic test accuracy studies than interventional studies[14], as CT scanners and protocols and the software and display devices used to interpret the imaging differ between institutions. However, I^2 heterogeneity was low, at 17.4%, and the SROC plot showed close approximation to the line of best fit in most studies. Whilst there is some evidence of a threshold effect on the SROC plot, with a negative correlation between sensitivity and false positive rate, the threshold cut off for detection of a positive finding cannot be explicitly varied, as it depends on the training and clinical practice of the interpreting clinician.

Agreeing with previous literature the most commonly reported features of OGI on CT were scleral deformity, lens malposition, altered anterior chamber depth and vitreous haemorrhage[27,28]. These abnormalities do not definitively identify OGI and correlation with clinical findings is vital. Intraocular air on CT is thought to be pathognomonic of OGI[18], but the two papers that commented on intraocular air included cases with reported apparent intraocular air on CT in the absence of OGI (although not by a specialist radiologist). Intraocular air detected on CT should therefore still be clinically correlated but if confirmed, active exploration for a penetrating injury is usually recommended. Air may be differentiated from other radiolucent materials on CT by measuring the Hounsfield units (HU) [29].

Only Allon et al. analyzed the influence of CT on the immediate treatment decisions in OGI, after evaluating 125 cases in an Israeli teaching hospital[30], concluding that CT did not change initial treatment, which was invariably primary repair, but helped plan subsequent management including vitrectomy, IOFB removal and orbito-facial reconstructive surgery. Possible benefits of CT before primary repair include the potential to combine vitrectomy with primary repair in the case of IOFB and awareness of orbital foreign bodies abutting the globe if they may be removed during primary repair. It may also provide potential prognostic information, such as optic nerve damage, absence of the lens[20], or scleral deformity which carry a worse prognosis, and screen for other urgent injuries such as traumatic brain injury, communication between the brain and orbit, and bony injury underlying lid injury, which may complicate repair.

Clinical assessment of globe disruption may be challenging when patients are distressed or uncooperative, have altered level of consciousness and significant associated injuries and in these circumstances, CT may be better able to assess an awake patient than physical examination. CT may also have particular use where specialist opinion is not rapidly available to alert non-specialists to the presence of eye injury, although with only a moderate sensitivity for OGI detection, there is no evidence that CT can replace the need for clinical assessment by an experienced ophthalmologist.

All except one included study were retrospective[24], highlighting the difficulties in conducting prospective studies of ocular trauma. Collection and analysis of real-world data on the outcomes of imaging in ophthalmic trauma by registries could enhance our understanding of the utility of a variety of imaging methods[31]. Registries may enable prospective and long term follow up data to be collected and analyzed[32,33], and patient reported outcomes to be understood[31,33,34], such as the International Globe and Ophthalmic Trauma Epidemiology study (IGATES)[32], an international registry reporting on real-world data from globe and ophthalmic trauma. Future studies should better define the performance of CT in IOFB detection, with a particular focus on the characteristics of IOFB that are more likely to be missed. In addition, prospective evaluation of protocols to maximize real-world IOFB detection and allow standardization of approaches between centres would be beneficial.

CONCLUSION

CT imaging has a moderate sensitivity for OGI detection and can be an effective Emergency Department screening tool but there is no evidence that it can replace ophthalmologist assessment, as it cannot exclude OGI or IOFB. The CT imaging findings most predictive of OGI were scleral deformity, change in AC depth, lens abnormality and vitreous haemorrhage. As the CT real-world sensitivity for OGI detection was only 69% (95% CI 51.4-82.0), if a high suspicion of IOFB is present, repeated clinical examination and multiple imaging modalities may be justified.

TABLES

Table 1. ***Characteristics of included studies. CT computed tomography; IOFB intraocular foreign body; OGI open globe injury; US ultrasound***

CT in IOFB and OGI detection								
Study Author	**Year**	**Country**	**CT reporting**	**Participants Total**		**Age range**	**Data collection**	**Study design (Rating)***
				Male	Female			
Arabi et al.[19]	2021	Iran	2 independent masked observers (1 neuroradiologist and 1 ophthalmologist)	133 patients and eyes		7-52	Apr 2016 – March 2020	Retrospective (3)
				115	18	Mean 39		
Arey et al.[18]	2007	USA	3 independent masked observers (2 neuroradiologist, 1 ophthalmologist)	46 patients/48 eyes		19-84	Oct 1998 – Sept 2003	Retrospective (3)
				38	8	Mean 36		
Chou et al.[21]	2016	Taiwan	2 independent masked observers (2 radiologists)	136 patients and eyes		18-84	Jan 2007 – June 2011	Retrospective (3)
				99	37	Median 41		
Crowell et al.[15]	2017	USA	3 independent masked observers	114 patients and eyes		2-88	Jan 2009 – Dec 2011	Retrospective (3)

			(1 neuroradiologist, 2 ophthalmologists)	83	31	Mean 39.5		
Gad et al.[16]	2017	USA	2 independent masked observers (2 neuroradiologists)	122 patients and eyes		NR	April 2011 – April 2016	Retrospective (3)
				NR	NR			
Hoffstetter et al.[25]	2010	German y	4 independent masked observers (4 radiologists) and original radiologist reporter	59 patients and eyes		7-91	2002 – 2007	Retrospective (3)
				42	17	Mean 29		
Joseph et al.[20]	2000	USA	3 independent masked observers (2 ophthalmologists, 1 radiologist)	142 patients and eyes		NR	1989 – 1993	Retrospective (3)
				NR	NR			
Yuan et al.[17]	2014	Taiwan	2 independent masked observers (2 radiologists)	75 patients/76 eyes		5 - 95 years	Jan 2002 – Jan 2012	Retrospective (3)
				56	19	Mean 45.1		
US in IOFB detection.								
Farvadin et al.[23]	2008	Iran	Ocular sonologist	58 patients and eyes		6-75	April 2006 – June 2007	Retrospective (3)
						Mean 24.5		

<table>
<tr><td></td><td></td><td></td><td></td><td>NR</td><td>NR</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">McNicholas et al.[24]</td><td rowspan="2">1995</td><td rowspan="2">Ireland</td><td rowspan="2">NR</td><td colspan="2">60 patients/61 eyes</td><td rowspan="2">5-74</td><td rowspan="2">NR</td><td rowspan="2">Prospective
(2)</td></tr>
<tr><td>53</td><td>7</td></tr>
<tr><td rowspan="2">Patel et al.[22]</td><td rowspan="2">2012</td><td rowspan="2">USA</td><td rowspan="2">NR</td><td colspan="2">27 patients and eyes</td><td>8-69</td><td rowspan="2">Jan 1998 – Dec 2008</td><td rowspan="2">Retrospective
(3)</td></tr>
<tr><td>26</td><td>1</td><td>Mean 33</td></tr>
</table>

*NR: not reported

**Rating scheme modified from the Oxford Centre for Evidence-based medicine[10]: 1 - Properly powered and conducted randomized clinical trial; systematic review with meta-analysis; 2 - Well-designed controlled trial without randomization; prospective comparative cohort trial; 3 - Case-control studies; retrospective cohort study; 4 - Case series with or without intervention; cross-sectional study; 5 - Opinion of respected authorities; case reports.

Table 2: Comparison of computed tomography (CT) findings in open and closed globe injury

CT finding	Open Globe Injury Total out of 361 Eyes (%)	Closed Globe Injury Total out of 474 Eyes (%)
Scleral deformity[15,18–20]	266 (74)	10 (2)
Altered AC depth[15,18–20]	194 (54)	25 (5)
Lens abnormality[15,18–20]	218 (60)	17 (4)
Vitreous hemorrhage[15,18–20]	211 (58)	24 (5)
Intraocular air[15,18–20]	13/69 (19)	2/93 (2)

Table 3: Summary of findings and GRADE[10] assessment

Outcomes	Relative Effect (95% CI)	No. of eyes (studies)	Certainty of the evidence (GRADE)
CT detection of OGI (compared to clinical examination)	Sensitivity 73.8%; 95% CI 66.4 - 80.0 Specificity; 92.6% 95% CI 88.2 -95.4; I^2–17.4%	851 (8 studies)	⊕⊖⊖⊖[1,2] Very low
CT detection of IOFB (compared to operative findings)	Sensitivity 68.7%; 95% CI 51.4 – 82.0 Specificity 99.1%; 95% CI 96.4 -99.8	294 (4 studies)	⊕⊕⊖⊖[1,3] Low
US detection of IOFB (compared to CT)	Sensitivity 86%; 95% CI 77-92 Specificity: N/A	92 (3 studies)	⊕⊖⊖⊖[1,4] Very low
GRADE Working Group grades of evidence **High quality:** Further research is very unlikely to change our confidence in the estimate of effect. **Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate. **Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. **Very low quality:** We are very uncertain about the estimate.			
1. Retrospective studies therefore low certainty of evidence. 2. Downgraded by one level as not all observers were masked therefore risk of bias, and unmasked observers would be expected to increase the accuracy of assessment. Not all CT protocols documented. 3. Upgraded by one level, as the expected effect of confounding (unmasked assessors) would be to increase sensitivity, which is low. Downgraded by one level for heterogeneity and uncertainty in imaging protocols, which were not all documented. 4. Downgraded as sonographers were not masked to clinical information, which would be expected to increase sensitivity.			

F**igure 1:** PRISMA flow diagram

Figure 2. a. Forest plot of the sensitivity and specificity of CT for OGI detection in comparison to clinical examination. **b.** Forest plot of the sensitivity and specificity of CT for IOFB detection in comparison to intraoperative findings. **c.** Forest plot of the sensitivity of US for IOFB detection in comparison to CT findings. TP, true positive; FP, false positive; FN, false negative; TN, true negative.

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