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CT Sinus and facial bones reporting by radiographers: Findings of an accredited postgraduate programme

Introduction

The use of functional endoscopic sinus surgery is a common surgical procedure within the United Kingdom (UK) National Healthcare Service (NHS) to preserve mucociliary function and expand drainage routes of the paranasal sinus when medical treatment has failed to resolve symptoms. It has been evidenced that reliance on clinical examination alone is unreliable for diagnosis.[1,2] The inclusion of Computed Tomography (CT) in the diagnostic pathway for sinus obstruction has been shown to alter treatment and management decisions through anatomical mapping and diagnosis of pathological disease.[1-3]

Likewise, in the initial diagnosis of maxillofacial trauma in the UK, CT is defined as the gold standard for cross-sectional imaging over Magnetic Resonance Imaging (MRI). Due to the ability to define bony anatomy (specifically infundibular complex, orbital lamina, cribriform lamina) and soft tissue.[4-7] In maxillofacial injuries, CT has been shown to have a high diagnostic value in diagnosing traumatic injuries that initial clinical assessment may miss due to associated soft tissue swelling of the surrounding anatomy,[8-9] providing quick initial examination of osseous and soft tissue injuries and further associated deep tissue injuries that may involve facial and optic nerves, muscles, glands, sinuses, and cranial injuries.[8] The evidence to further support the use of CT in the UK maxillofacial trauma pathway has included speed of examination,[10] and the cost-effectiveness to image and report the examination against its next nearest viable imaging modality. Which in the UK healthcare system, the economic costs of services are regulated by the Department of Health through NHS England (the executive non-departmental government body) to standardize all healthcare costs in the NHS. The 2016/17 tariff for a CT facial bones scan and reporting was £78 + £22, as opposed to an MRI scan and reporting of £124 + £22.[11] For patient health and safety reasons, and to reduce the potential risk of harm in imaging unconscious or sedated patients with no clinical history, CT is recommended as the first line investigation in facial trauma as opposed to MRI, through the National Insititue for Health and Care Excellence guidelines.[12]

The UK NHS service delivery evidence for implementing reporting radiographers has been demonstrated by a recent UK Royal College of Radiologists (RCR) survey[13] highlighting the current demand (29% rise in patient referrals for CT 2014-15)[13] and capacity (radiologist workforce shortages) issues in UK radiology. The RCR estimated 230,000 patients in 2016 were waiting too long for diagnostic reports (over 31 days), 12,178 of these included CT and MRI scans.[14] The evidence revealed 75% of English NHS trusts had a backlog of reporting.[14] The estimated cost in the short term to reduce the backlog in 2015 was £88.2m, an increase of 57% from the previous year, through outsourcing to private tele-reporting companies.[14] The RCR consider this cost to be equivalent to 1,032 NHS consultant radiologists salaries.[13] A recent NHS England report[15] reviewed the effect of outsourcing had been unsuccessful not only due to high costs, but clinicians had limited access to discuss complex cases with private providers/reporters leading to unnecessary repeat imaging which further increased the reporting demand. NHS England[15] highlighted the impact the workforce deficit had on diagnostic services as a significant bottleneck in the system. NHS England[13] recommended the workforce restrictions need addressing through multiple national initiatives to resolve the low number of reporters. One long-term plan to achieve sustainable and economic solutions to the sector supported by the Department of Health[16], the Society and College of Radiographers and the RCR,[17] is the introduction of a skills mix of radiographer and radiologist team working in reporting, funded in part by NHS England[18] with a £15m four-year initial investment to support early and fast reporting through a

"National Diagnostics Capacity Fund." With plans to finance amongst other areas an increase of radiographers and radiologists to improve patient outcomes.

The UK healthcare system definitions of the role of a consultant radiologist working in the NHS is set by the RCR. This clinical role is described as performing examinations and procedures in complex diagnostic and therapeutic imaging investigations and interventions, and the reporting of medical images in trauma, disease, and cancer.

The UK healthcare role of a diagnostic radiographer (commonly known globally as a radiologic technologist, or medical radiation technologist), has a very diverse career pathway and differs slightly from other foreign healthcare systems, although there is common scope of practice in the role globally, which includes imaging of human anatomy, enforcement of radiation protection, justification of examinations, and patient care. In the UK NHS, there are many sub specialities defined by the different imaging modalities, and each has role extension and advanced practice routes to consultancy level through master's education. Within this study, the role of the reporting radiographer is explored. Since 1994, the UK NHS has developed and implemented reporting radiographers to analyse, interpret and write the final examination report on a range of plain film, mammography, CT, MRI, and nuclear medicine examinations. It is noted that other countries such as the Republic of Ireland, Finland, Norway, Australia, New Zealand and South Africa have also been developing and embedding reporting radiographer roles for some years within their healthcare systems, that is similar to the UK approach.

The postgraduate reporting course in CT sinus and facial bones in this study was accredited by the UK College of Radiographers in 2011. The course runs consecutively with the postgraduate certificate in CT head reporting, as a part-time work based module (20 credits at Level 7) over a period of 9 months. The curriculum and teaching were developed jointly by consultant radiologists and reporting radiographers. The assessment criteria for the module includes a written case study, a record of a minimum of 125 clinical reports and an Objective Structured Examination (OSE).

The aim of this study was to investigate primarily, whether a cohort of radiographer's accuracy level in CT reporting of sinus and facial bones examinations is equal or equivalent in comparison to a radiologists performance level after a period of training (academic and clinical). This will be measured through the analysis of OSE results of the participants who have completed the programme (n=6) against the defined OSE radiologist reference standard, accompanied by an exploration of the relationship between the students' t-test performance against an alternative comparator (the published results from peer-reviewed literature in CT sinus and facial bone observer performance by radiologists).

Method

Ethics

This study has received ethics and governance approval agreed by the Faculty of Health and Wellbeing Research Ethics Committee.

Assessment of observer performance

The programme of study adhered to the postgraduate pathway of assessments for the clinical reporting modules at our university. With a final assessment of competence through an OSE, consisting of 25 adult (>18 years) retrospective CT sinus and facial bones cases (index test) under controlled examination conditions.[19] Using low-level lighting and high definition reporting monitors[20] that adhere to RCR reporting standards[21] (42cm, 1280 x 1084 screen resolution, >170 cd/m2 luminance, ≥250:1 luminance contrast ratio). The CT studies were presented in Digital Imaging and Communications in Medicine (DICOM) format on KPACS software (Image Informations Systems Ltd, London, UK)[22] to allow manipulation by the reader.[21]

Reference standard

A retrospectively collected and anonymised DICOM archive of CT sinus and facial bone examinations with referral histories (gender, age, clinical symptoms and previous medical history) and clinical reports was used in the construction of the OSE examination. Each case was independently reported by three consultant radiologists (each blinded to the original report, to minimise verification and work-up bias). The reference standard report for each examination was established through review and consensus of the three consultant radiologists[23] reports by the programme panel and external examiner (independent consultant radiologist). This process verified that an appropriate range of target conditions (and diagnostic thresholds) was incorporated to reflect the postgraduate level knowledge and competence. The test banks contained negative cases (48%) and subtle and characteristic positive (single and multi-site) pathological cases (disease prevalence 52%).

Target conditions

In the paranasal sinus cases, positive target conditions included: the presence of soft tissue lesions, polyps, retention cysts, and mucoceles; obstruction of the mucociliary drainage (ostium, ostiomeatal complex, infundibulum, and middle meatus) and moderate mucosal changes (without fluid or opacification signs). Disease distribution of diffuse mucosal thickening was shown in multiple sinuses (unilateral or bilateral) such as Rhinosinusitis (short-term symptomatic inflammation of the nasal cavity and paranasal sinus) and Sinusitis Inflammation of a single sinus cavity. Additionally, secondary pressure effects of destruction, sclerosis or decalcification of the bony sinus walls from adjacent lesions and/or postsurgical interventions were included. Normal variants (to reduce spectrum bias) such as a deviated nasal septum, concha bullosa, paradoxical curvature of middle turbinates, uncinate bulla, onodi cells, and hypoplastic frontal sinus, Haller cells, bulla ethmoidalis, posterior nasal septal air cells, agger nasi cells (not causing mechanical obstruction of frontal recess area), and aerated crista galli seen in isolation, were deemed normal in this study.

For the facial bones, target cases included examples of orbital blowout fractures, complex midface injuries with multiple osseous fractures (including Le Fort I, II, III), mandibular fractures, orbital trauma, associated soft tissue emphysema, muscle, dental complications, and herniated bone fragments. Normal variants for the facial bones cases included sutures, fissures, artifacts of partial-volume averaging, and dental/ocular implants.

Index test

The scans were presented in standard CT protocols with a slice thickness of 3mm to 5mm coronal, axial, and sagittal data sets. The volume data was reconstructed into adjustable bone (window width 2000 Hounsfield Units (Hu) and window level 450 Hu) and soft tissue (window width 400 Hu and level 50 Hu) algorithms. The use of axial, coronal[8] and sagittal[24-25] CT reconstructions allowed the radiographers to review the triplanar (horizontal, sagittal and coronal) osseous struts[8] for trauma, and the coronal views to approach the osteomeatal unit in paranasal sinus examinations.

Study population

The six reporting radiographers (RR1-6) were provided with the referral clinical symptoms, including gender, age (18-92 years), and the referral source (Accident and Emergency, General Practitioner, in-patient and out-patient). The sampling method and inclusion criterion of the population in this observer performance test was randomly selected in both frequency and severity of target conditions. It was acknowledged that the patient history for CT sinus investigations could be deemed misleading, as age and gender distribution of cases has been evidenced to be inconsistent with pathological distribution. The correlation between symptoms of pain, tenderness, pressure, congestion, discharge, headache, dysosmia, anosmia/hyposmia, and nasal blockage do not always associate to normal/abnormal findings.[26-28]

Test bank instructions

The candidates were asked to decide if the examination was normal or abnormal, and provide a detailed report of findings (describing the exact anatomical location) in a free text response. Including the primary condition and any secondary mass effects. When identifying and classifying abnormal sinus appearances, details of the soft tissue disease such as localised thickening of the wall, hypertrophic mucosa, or focused opacification of the sinus (singular or in combination/expansion into adjoining sinus) were used. The presence of horizontal fluid levels within a sinus cavity, or if a lesion was seen, the size (in mm) and lesion/fluid characteristics (with associated bone erosion/destruction/extension in sinuses) were required.

The participants in this programme were not taught the Lund-Mackay system,[29-30] although it has been widely adopted by amongst others the American Academy of Otolaryngology as a system for preoperative planning for chronic rhinosinusitis. Although it has scored better than other CT staging systems for chronic sinusitis (such as Jorgensen, May and Levine, Newman,[31] Kennedy, and Harvard).[32] The Lund-Mackay system[28] has been shown not to be a significant predictor to influence patient outcomes[1,32] and as such was not adopted as the candidates were also required to comment on the non-sinus facial anatomy as well.

Statistical analyses

Responses were classified as true positive (TP), and true negative (TN) for correct answers, false positive (FP) or false negative (FN) for incorrect answers. With the use of fractions (whole and partial) as described in a previous study.[33] Each exam paper was triple reviewed for concordance of marks, by two academics and an external examiner (consultant radiologist) to verify an accurate and fair marking process was followed in-line with the established reference standard reports. Sensitivity, specificity, and accuracy were calculated using standard measures of observer performance using a 2x2 contingency table,[34] with Fisher's exact test (displaying two tailed p-value due to the small sample size). Mean values were further estimated, and inter-observer variation was observed using Cohens Kappa (k) to correct for chance agreement,[19] with Fleiss Kappa (k) for multiple reader reliability agreement with 95% confidence intervals (95% CI) and standard error (SE). Further review using positive and negative predictive values (PPV and NPV) was run to evaluate the performance of the reader influenced by the disease prevalence of the test. Likelihood ratios to assess the value of performing the test (not disease prevalence dependent). Diagnostic odds ratios (DoR) as a global measure of RR1-6 diagnostic accuracy (not disease prevalence dependant, but reliant on the spectrum of the target conditions used). Summary receiver operating characteristic (ROC) curves were plotted with the area under the curve (AUC) estimated for the discriminative power of the observers between the target conditions and negative cases.

Alternative comparator

A literature search was performed to identify an alternative comparison reference standard from studies reporting observer performance data in CT sinus and facial bones examinations (index test) for both trauma and sinus pathology (target conditions). The search used Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library Oct 2016, Issue10) and the following databases from 1995 to 2016: MEDLINE, CINAHL, and PubMed Central. While also conducting searches through subject specific electronic databases (ScienceDirect and Wiley Online), and Google Scholar. Further studies were identified for possible inclusion through review of reference lists from studies found in the initial search. Free text words and Boolean operator search terms were included to identify specific and exact matches. Selection criteria included reviews of all cohort studies that used CT imaging as the index test for the target conditions. The patient population was defined from either a clinical examination or clinical diagnosis, and a predefined radiological reference standard report in the study method. All observer groups included radiologists; two also included maxillofacial surgeons as readers. The published study data defined the results in either TP, FP, TN, and FN or derivable from data within the published study (such as sensitivity, specificity, accuracy). It was noted from the

preliminary review of the published studies that no control group was included in the studies, but all had a defined reference standard to fulfil the criteria for acceptance. Found studies were reviewed for methodological quality against the Quality of Assessment of Diagnostic Accuracy Studies (QUADAS-2) criteria.[35] There was minor variation in methods to display the results and therefore, where possible, re-analysis of the published data to conform to standard 2x2 contingency table. The analysis was performed using Cochrane Diagnostic Test Accuracy review software (Review Manager (RevMAn), The Cochrane Collaboration, Copenhagen: Denmark)[36] and Meta-DiSc software (Unit of clinical Biostatistics, Ramon y Cajal Hospital, Madrid: Spain).[37] Sensitivity and specificity were confirmed from the published data and displayed in a standardized interpretation model of forest plots as a graphical representation of the results of multiple trials and studies of the same intervention, with standardised interpretation model meta-analysis of results using pooled estimates, Chi-square with p-values (large sample distribution), and inconsistency (I-square) to identify any heterogeneity or consistency of results, with degrees of freedom (df). Summary ROC curve plots were used to assess and illustrate the performance (discrimination threshold) through plotting the true positive rate (TPR) and false positive rate (FPR) of the range of multiple published results and a summary AUC calculated.

Results

Observer performance

The mean RR1-6 sensitivity was 97.5% (95% CI 91.3-99.7), specificity 93.6% (95% CI 85.1-98), and accuracy 95% (95% CI 73.3-98.2), with significance of $p < 0.000$ shown in Table 1. The mean RR1-6 k values for observer performance across all test banks combined (Cohens k=0.8924, 95% CI 71.3-100 and Fleiss k=0.9121, 95% CI 72.1-100) displayed a high k score of agreement (Table 2). The mean RR1-6 AUC was 0.9822 (plotted in Table 4), the summary random effects model is displayed in Table 3.

Alternative comparator

For the literature review results, ten studies were found (n=847 sample size in total) for the CT sinus observer performance studies. Eleven studies were identified (including n=2428 sample size in total) for CT facial bones observer performance studies. The methodological quality of these studies was satisfactory for inclusion in this paper. However, it is noted there is the potential for bias in certain papers related to the anatomical area of the facial bones/sinus reviewed for focused target conditions. Results shown in ROC plots displayed in Table 5 mean AUC of 0.9533 (sinus target conditions) and Table 6 Mean AUC 0.9374 (trauma target conditions) as an alternative comparator to the RR1-6 AUC of 0.9822 (Table 4). Table 7 forest plot demonstrates the alternative comparison sensitivity estimate of 90% (95% CI 87-92) and Table 8 specificity of 78% (95% CI 73-82) for CT sinus observer performance. With a similar sensitivity estimate of 87% (95% CI 85-89) in Table 9 and specificity of 89% (95% CI 87-91) in Table 10, for CT facial bones as an alternative comparator for the RR1-6 results. The available literature evidence base when used in comparison to this cohort study suggests the students could diagnose target conditions with a high degree of confidence.

Discussion

The main findings of the RR1-6s performance in CT sinus and facial bone reporting display a high degree of sensitivity, specificity, and accuracy to the reference standard and current evidence base when assessed in an academic setting. Discordance of participants reports included minor FP error over the degree of mucosal thickening required to confirm chronic sinus conditions in a case referred for other conditions. This raises the issue of incidental findings in CT examinations of patients who are asymptomatic, giving FP results which previous studies have quoted various FP ranges of 2.1%[38] – 5.2%.[39] Moreover, studies have questioned whether minor mucosal thickening of 4-5mm has any clinical significance and may be related to normal variance or function of the physiologic nasal cycle,

and not correlated to allergic seasonal variance.[40] A further FP case involved a case of correct diagnosis of complete sinus opacification of the maxillary antrum but queried if there was an underlying lesion associated. Although, in this instance, there was no mixed signal density of the fluid or associated bony erosion or remodelling. It does raise the issue of correct identification of disease in a fluid filled sinus cavity which may mask underlying polyposis, lesion or a retention cyst.

Common satisfaction of search errors included FN errors of adjacent or additional conditions including deossification of ethmoid septa from bordering nasal polypi, and small areas of further mucosal thickening in adjacent sinuses, and also an FN error of a small orbital floor herniation into the maxillary antrum in a case of complex facial trauma involving Le Fort III fractures.

Within facial injuries, Le Fort[41] described and detailed facial trauma patterns to a standard that is still used today to classify the various possible traumatic bone fracture patterns to the structural pillars of the facial skeleton. Limitations of this system include the lack of associated soft tissue injury identification, which may involve multiple anatomical areas with varying degrees of significance including orbital, sinus, nerve and ligamentous involvement, in the diagnosis of unstable fractures primarily with anterior or lateral displacement which may involve further injuries such as sagittal fractures of the maxilla and palate.[42] Although uncommon, they alter management due to the significant instability and surgical management required to reduce and fixate the fragments. Indeed, any maxillofacial trauma has the potential for disfigurement, disability and facial nerve damage which can significantly alter patient treatment and management.

Gentry et al[8,43] advise the use of axial and coronal CT reconstructions for facial trauma interpretation which allows for specific search patterns of the facial struts. The horizontal, sagittal and anterior coronal struts (perpendicular to each other) allowing compartmentalisation of maxillofacial anatomy into oral, nasal, paranasal, and orbital zones. Enabling identification of osseous injuries and the structural attachments of facial and extraocular muscles and soft tissue strucures,[43] being particularly useful in structures such as the cribriform plate, hard palate, vomer, alveolar ridge, and pterygopalatine fossa which may give rise to FN reports if not reviewed thoroughly. The Gentry et al[8] system is similar to various other search patterns such as the Buttress system (four transverse and vertical buttresses) by Hopper et al.[44] used for midface trauma, which has a correlation to more significant and life-threatening outcomes. Essentially Gentry et al[8] advise the coronal and axial planes as ideal for reviewing the facial structures. For this study, we also supplied sagittal plane reconstructions as it supported diagnosis for herniation of structures, which allowed additional supplementary evidence of traumatic injuries to the orbital floor, malar strut, maxillary wall displacement and zygomaticomaxillary fractures and frontal sinus anatomy.[24,25]

These evaluation findings have the potential for impact beyond academia, by embedding this defined scope of practice into radiographer advance practice roles. It is hoped future studies will determine the impact and outcomes of this research in conjunction with other reporting radiographer work to reduce reporting backlogs, in comparison to nationally evidenced delays.[14] Additionally, it has been previously reported that radiographers are an economical and viable option in CT reporting[45] and further review would be beneficial given the current NHS financial restraints. The impact of this study is to supplement the growing evidence base of reporting radiographers outside of plain film reporting and into cross-sectional modalities[33,46] to support service delivery and patient outcomes. It has been previously shown[47] that multi-modality radiographer reporting can influence and benefit patient treatment and management to improve outcomes and care. Which is a major factor in advancing the role development of radiographers in healthcare systems both nationally and internationally.

Limitations

A weakness of the literature review included the relatively small number of identified studies, and sample size within each (index tests, and observers). It was noted that the literature on this subject is

low and therefore this will impact upon the results to be generalisable. Another significant weakness to identify is the heterogeneity identified in found literature, of which some focused on individual anatomical areas or specific target conditions. Additionally, the author recognises that this review of found literature re-analysed the published data according to standard 2x2 contingency table to confirm its results. Although, other models do exist, it was deemed beyond the scope of this review to discuss the statistical grounds for recommendations of different interpretation models.

Given the risk of bias and heterogeneity of found studies, an opinion could be made for not providing a review of these results to the found literature. However, it was believed that additional value was gained from it, despite limitations from the limited published research in this clinical area.

Conclusions

In this study, the overall aim was to investigate the performance of a group of radiographers at the end of an accredited postgraduate programme in clinical reporting of CT sinus and facial bones investigations. The results displayed high levels of agreement when compared with the OSE reference standard. The evaluation and comparison of results to the published literature using standardised interpretation models suggest this cohort of participants can report selected CT investigations with satisfactory accuracy under examination conditions in an academic setting. The conclusions that can be reached from this preliminary study are limited by the method and sample size. However, the collaboration and integration of skills mix reporting for the benefit of patient outcomes have previously been shown in other reporting modalities, and it may also benefit CT sinus and facial bones reporting in the future. The impact of the data from this study could help to increase the evidence base of advanced practice roles, although it is restricted currently to the defined roles available to UK radiographers. This may not be at present be globally generalisable to other healthcare systems; it is noted other countries are developing and implementing reporting radiographer roles to benefit service provision through healthcare improvement initiatives.

Recommendations from this study include further research on a large cohort of radiographers within a clinical practice environment to allow consensus on the results. Recommendations for radiographers reporting within this area include adherence to an agreed scheme of work, routine governance, regular audit, and continuing professional development to support advanced practice roles.

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Tables

Table 1. Summary RR1-6 observer performance results from the OSE.

Reporting Radiographers	Number of cases	TP	TN	FP	FN	Accuracy Acc	Accuracy 95% CI	Sensitivity Sens	Sensitivity 95% CI	Specificity Spec	Specificity 95% CI	Fisher's Test *p*-Value
RR1	25	12	11	1	1	0.920	0.701-0.993	0.923	0.640-0.998	0.917	0.615-0.998	0.000
RR2	25	13	11.5	0.5	0	0.980	0.778-0.980	1.000	0.753-1.000	0.958	0.672-1.000	0.000
RR3	25	13.5	10	1	0.5	0.940	0.727-0.980	0.964	0.712-1.000	0.909	0.587-0.998	0.000
RR4	25	11.5	12	1	0.5	0.940	0.725-0.980	0.958	0.672-0.998	0.923	0.640-0.998	0.000
RR5	25	15	9	1	0	0.960	0.755-0.960	1.000	0.782-1.000	0.900	0.555-0.997	0.000
RR6	25	13	12	0	0	1.000	0.805-1.000	1.000	0.753-1.000	1.000	0.735-1.000	0.000
mean						0.950	0.733-0.982	0.975	0.913-0.997	0.936	0.851-0.980	0.000

Table 2. Summary RR1-6 observer performance results from the OSE.

Reporting Radiographers	Number of cases	Cohens Kappa Unweighted k	Cohens Kappa 95% CI	Cohens Kappa SE	Cohens Kappa Linear Weighted k	Cohens Kappa 95% CI	Cohens Kappa SE	Fleiss Kappa k	Fleiss Kappa 95% CI	Fleiss Kappa SE
RR1	25	0.8397	0.6267-1.000	0.1087	0.8397	0.6266-1.000	0.1087	0.840	0.627-1.000	0.109
RR2	25	0.9599	0.8498-1.000	0.0562	0.9599	0.850-1.000	0.0561	0.960	0.882-1.000	0.040
RR3	25	0.8777	0.6879-1.000	0.0969	0.8777	0.6881-1.000	0.0967	0.878	0.744-1.000	0.068
RR4	25	0.8800	0.6938-1.000	0.095	0.8800	0.694-1.000	0.0949	0.880	0.748-1.000	0.067
RR5	25	0.9153	0.7526-1.000	0.083	0.9153	0.7532-1.000	0.0827	0.915	0.753-1.000	0.083
RR6	25	1.000	1.000-1.000	0.000	1.000	1.000-1.000	0.000	1.000	1.000-1.000	0.000
mean		0.8924	0.7131-1.000	0.0909	0.8998	0.7131-1.000	0.0909	0.9121	0.721-1.000	0.0611

Table 3. Summary random effects model of RR1-6 observer performance results from the OSE.

Reporting Radiographers	Number of cases	Positive Predictive Value PPV	Positive Predictive Value 95% CI	Negative Predictive Value NPV	Negative Predictive Value 95% CI	Positive Likelihood Ratio +LR	Positive Likelihood Ratio 95% CI	Negative Likelihood Ratio -LR	Negative Likelihood Ratio 95% CI	Diagnostic Odds Ratio DOR	Diagnostic Odds Ratio 95%CI
RR1	25	0.923	0.712-0.993	0.917	0.688-0.993	11.077	1.685-72.816	0.084	0.013-0.556	132.00	7.336-2375.2
RR2	25	0.963	0.776-0.963	1.000	0.780-1.000	12.536	1.902-82.629	0.039	0.003-0.591	324.00	9.555-10545.3
RR3	25	0.931	0.747-0.966	0.952	0.698-1.000	10.607	1.632-68.924	0.039	0.003-0.601	270.00	8.220-8868.8
RR4	25	0.920	0.705-0.960	0.960	0.745-1.000	12.458	1.888-82.200	0.045	0.003-0.684	276.00	8.420-9047.0
RR5	25	0.938	0.778-0.938	1.000	0.716-1.000	7.104	1.601-31.516	0.036	0.002-0.559	196.33	7.235-5328.1
RR6	25	1.000	0.812-1.000	1.000	0.796-1.000	25.071	1.652-380.54	0.037	0.002-0.566	675.00	12.428-36659.7
mean		0.943	0.741-0.967	0.917	0.724-1.000	10.858	5.060-23.299	0.049	0.018-0.137	249.72	62.463-998.35

Table 4. Summary ROC Curve of plots of the range of RR1-6 observer performance from the OSE.

AUC = 0.9822
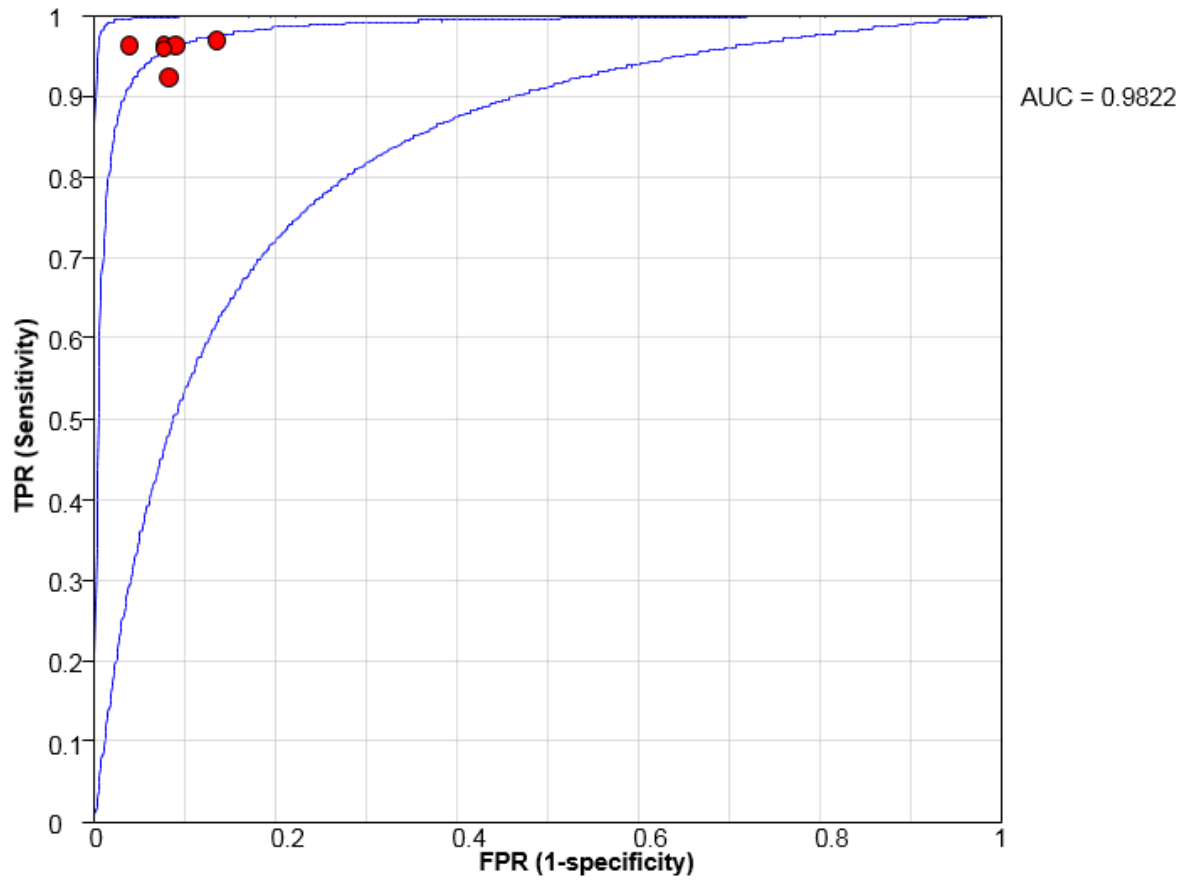
Table 5. Summary ROC curve plots of the range of observer performance from published literature results in CT sinus studies.

AUC = 0.9533
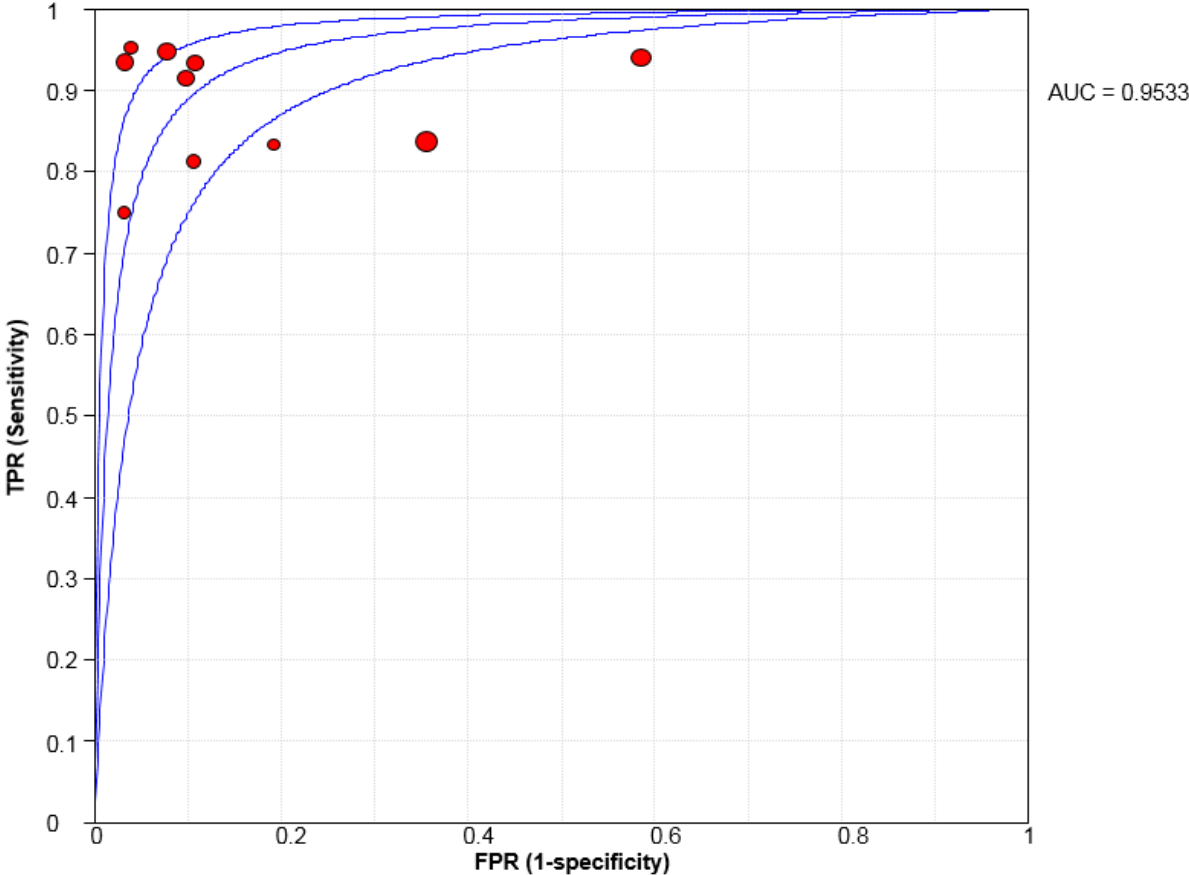
Table 6. Summary ROC curve plots of the range of observer performance from published literature results in CT trauma studies
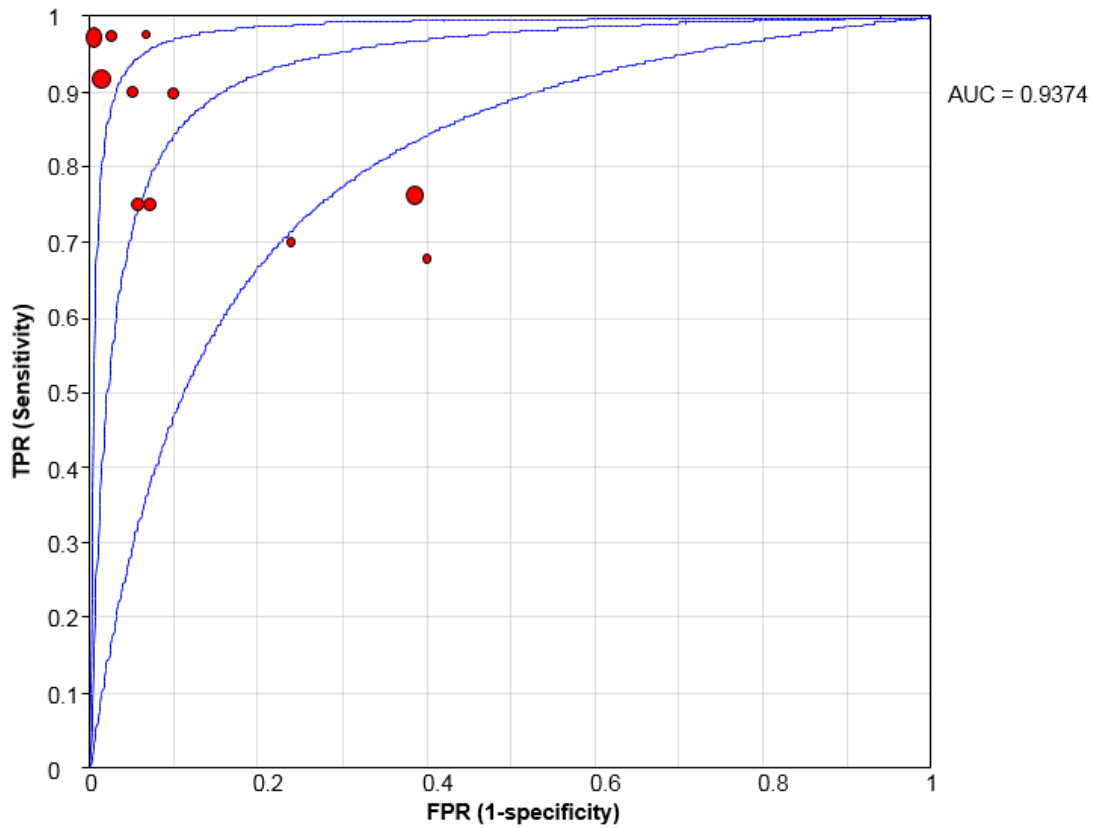
AUC = 0.9374

Table 7. Forest plot of observer sensitivity performance from published literature in CT sinus studies.

CT Sinus Papers	Sensitivity (95% CI)	
1. Awaida et al. 2004	0.81	(0.64 - 0.93)
2. Bhattacharyya. 2003	0.94	(0.88 - 0.98)
3. Goodman et al. 1995	0.93	(0.84 - 0.98)
4. Hagtvedt et al. 2003	0.95	(0.76 - 1.00)
5. Islam et al. 2016	0.94	(0.81 - 0.99)
6. Lindbaek et al. 1996	0.84	(0.77 - 0.89)
7. Sharifian et al. 2006	0.95	(0.87 - 0.99)
8. Visca. 1995	0.77	(0.48 - 0.94)
9. Wippold et al. 1995	0.83	(0.52 - 0.98)
10. Younis et al. 2002	0.91	(0.78 - 0.98)

Pooled Sensitivity = 0.90 (0.87 to 0.92)
Chi-square = 16.66; df = 9 (p = 0.0543)
Inconsistency (I-square) = 46.0 %
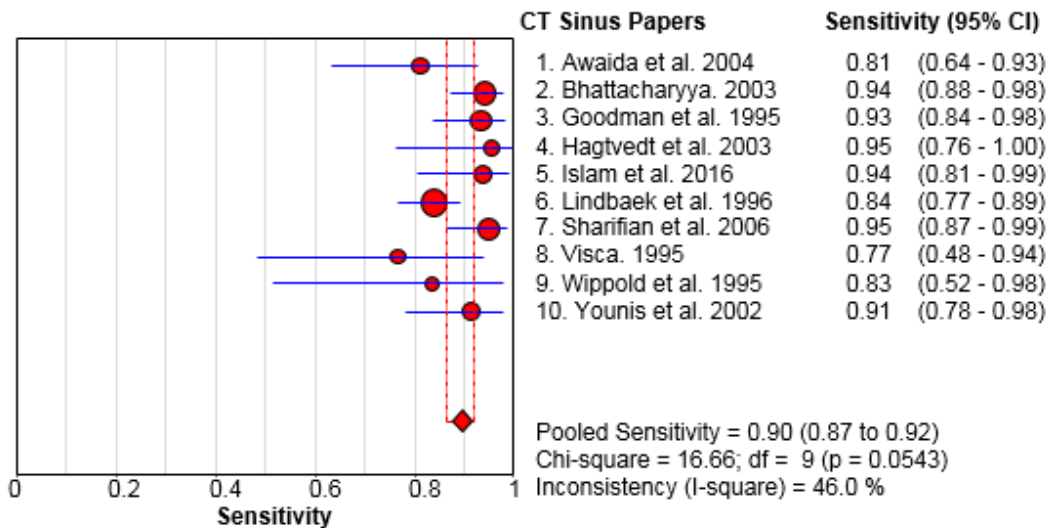
Table 8. Forest plot of observer specificity performance from published literature in CT sinus studies.

CT Sinus Papers	Specificity (95% CI)	
1. Awaida et al. 2004	0.89	(0.67 - 0.99)
2. Bhattacharyya. 2003	0.41	(0.30 - 0.54)
3. Goodman et al. 1995	0.89	(0.72 - 0.98)
4. Hagtvedt et al. 2003	0.96	(0.80 - 1.00)
5. Islam et al. 2016	0.97	(0.85 - 1.00)
6. Lindbaek et al. 1996	0.64	(0.51 - 0.76)
7. Sharifian et al. 2006	0.92	(0.81 - 0.98)
8. Visca. 1995	1.00	(0.78 - 1.00)
9. Wippold et al. 1995	0.81	(0.50 - 0.97)
10. Younis et al. 2002	0.90	(0.77 - 0.97)

Pooled Specificity = 0.78 (0.73 to 0.82)
Chi-square = 90.99; df = 9 (p = 0.0000)
Inconsistency (I-square) = 90.1 %
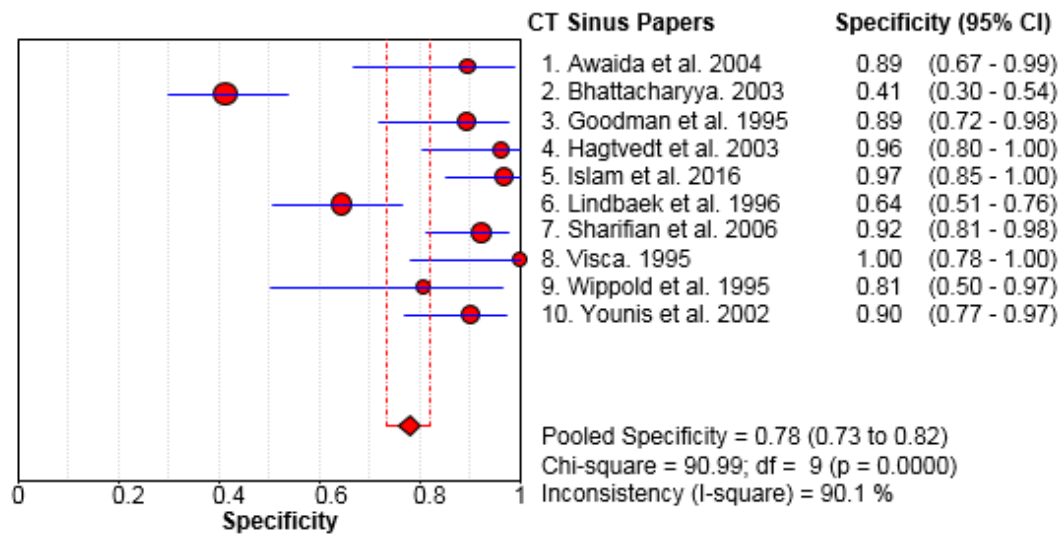
Table 9. Forest plot of observer sensitivity performance from published literature in CT facial trauma studies.

CT Trauma Papers	Sensitivity (95% CI)	
1. Arey et al. 2007	0.70	(0.49 - 0.87)
2. Baek et al. 2013	0.90	(0.79 - 0.96)
3. Chou et al. 2016	0.75	(0.63 - 0.85)
4. Grechushkin et al. 2016	0.92	(0.88 - 0.94)
5. Johari et al. 2016	0.98	(0.90 - 1.00)
6. Joseph et al. 2000	0.75	(0.65 - 0.83)
7. Kim et al. 2010	0.97	(0.94 - 0.99)
8. Marinaro et al. 2007	0.90	(0.78 - 0.97)
9. Reuben et al. 2015	0.68	(0.38 - 0.90)
10. Whitesell et al. 2015	0.76	(0.70 - 0.81)
11. Wilson et al. 2001	1.00	(0.83 - 1.00)

Pooled Sensitivity = 0.87 (0.85 to 0.89)
Chi-square = 105.41; df = 10 (p = 0.0000)
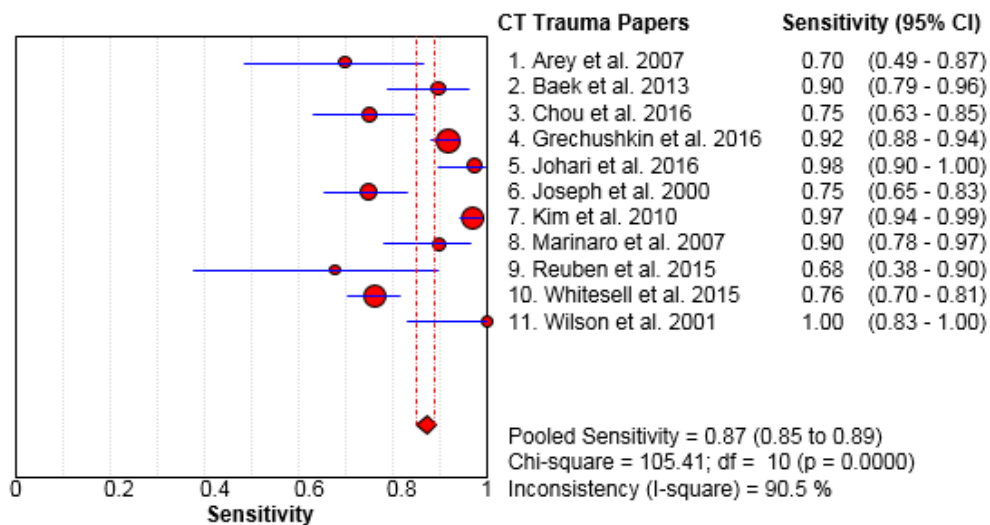Inconsistency (I-square) = 90.5 %

Table 10. Forest plot of observer specificity performance from published literature in CT facial trauma studies.

CT Trauma papers	Specificity (95% CI)	
1. Arey et al. 2007	0.76	(0.53 - 0.92)
2. Baek et al. 2013	0.90	(0.78 - 0.97)
3. Chou et al. 2016	0.94	(0.86 - 0.99)
4. Grechushkin et al. 2016	0.99	(0.97 - 1.00)
5. Johari et al. 2016	0.98	(0.90 - 1.00)
6. Joseph et al. 2000	0.93	(0.86 - 0.97)
7. Kim et al. 2010	1.00	(0.98 - 1.00)
8. Marinaro et al. 2007	0.95	(0.83 - 0.99)
9. Reuben et al. 2014	0.60	(0.25 - 0.88)
10. Whitesell et al. 2015	0.61	(0.55 - 0.67)
11. Wilson et al. 2001	0.95	(0.77 - 1.00)

Pooled Specificity = 0.89 (0.87 to 0.91)
Chi-square = 244.52; df = 10 (p = 0.0000)
Inconsistency (I-square) = 95.9 %