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Statistical review of radiology registrars after hours computed tomography reporting accuracy

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Statistical review of radiology registrars after hours computed tomography reporting accuracy

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A Research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Medicine in Diagnostic Radiology.

Johannesburg, 2012

Declaration

I, Owen Dale Terreblanche, declare that this thesis is my own work. It is being submitted for the degree of Master of Medicine in Diagnostic Radiology in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

……

Dr OD Terreblanche

On this, the 13th day of March 2012

Dedication

I dedicated this to my wife Joi, for her unending support.

Publications & Presentations

- This work has been published in Acta Radiologica 2012; 53 61-68
- The work was presented as an oral presentation at the SORSA-RSSA imaging conference, Durban, March 2011
- Preliminary results were presented as poster at the University of the Witwatersrand Research day, 2011 (First place in category received)

Abstract

Background:

There is a heavy reliance on registrars for afterhours CT reporting with a resultant unavoidable error rate. This study was done to determine this error rate.

Material and Methods:

A 2 month prospective study was undertaken. Provisional CT reports issued by the registrar on call were reviewed information relating to the errors made during the call were recorded and analyzed.

Results:

1477 CT scans were performed with an overall error rate of 17.1%. A significant difference was found between trauma (15.8%) compared to non-trauma scans (19.2%). The difference between emergency scans (16.9%) and elective scans (22.6%) was not significant. Abdominopelvic scans elicited the highest error rate (33.9%). Increasing workload resulted in a significant increase in error rate. Missed findings were the most frequent errors (57.3%). Error rate decreased with increasing year of training.

Acknowledgements

I acknowledge the invaluable assistance and guidance of my supervisor, Prof S Andronikou as well as the support and assistance of my clinical colleagues, Dr. T Brown, Dr. PE Boshoff and Dr. LT Hlabangana in the data collection and preparation of the manuscript.

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Table of Contents

Declaration ii

Dedication iii

Publications & Presentations iv

Abstract v

Acknowledgements vi

Table of Contents vii

List of Figures ix

List of Tables x

1.0 Introduction 1

1.1 Background: 1

1.2 Literature Review: 1

1.3 Objective: 2

2.0 Material and Methods 3

2.1: Study Design: 3

2.2 Current Practices: 3

2.3 Data Collection: 4

2.4 Statistical Analysis: 5

3.0 Results 7

3.1 Overall: 7

3.1 Error Type: 7

3.2 Workload: 8

3.3 Year of Training: 9

3.4 Body region scanned: 10

3.5 Indication for scan: 11

3.6 Time of scan: 12
3.7 Example of errors 13
4.0 Discussion and Conclusion 21
Appendix 27
References 28

List of Figures

Figure 3.1: Scatter graph of the average number of errors per number of scans per call. .. 9

Figure 3.2: Major error in a CT scan of a Head. 13

Figure 3.3: Minor error in a post-contrast CT scan of an abdomen. 14

Figure 3.4: Major error in a pre-contrast CT scan of the C-spine 15

Figure 3.5: Major error in a pre-contrast CT Brain. 16

Figure 3.6: Major error in a post contrast CT abdomen. 17

Figure 3.7: Major error in a pre-contrast CT C-spine in trauma. 18

Figure 3.8: Major error in a non-contrast CT brain. 19

Figure 3.9: Major error in a precontrast CT C-spine in trauma. 20

List of Tables

Table 3.1: Analysis of error rate by workload 8

Table 3.2: Analysis of CT readings according to year of training..... 10

Table 3.3: Analysis of CT reading errors according to body region scanned..... 11

Table 3.4: Analysis of CT reading errors according to the indication for scanning..... 12

Table 4.1: Summary of findings of relevant literature compared with our results..... 26

1.0 Introduction

1.1 Background:

Medical imaging has become an integral part of patient diagnosis and management. Management decisions need to be taken promptly regardless of the time of presentation of the patient (1, 2). Our department, as with many other training and academic facilities, relies on radiology registrars to cover afterhours imaging. These imaging studies done at night and on weekends are usually reviewed the following day by a qualified consultant radiologist.

1.2 Literature Review:

Plain radiographs, MRI, ultrasound and contrast studies all have their own role in emergency medicine but computed tomography (CT) is the primary modality in the emergency setting. Indeed CT has been described as "the single most important diagnostic modality in the emergency department with efficacy in both traumatic and non-traumatic conditions" (3).

Various studies have analyzed the discrepancies between the reports of the trainee radiologist and the qualified radiologist for afterhours procedures. These studies have found discrepancy rates between registrars and consultants to be between 1.4% and 29.5 %. (1, 4, 5).

1.3 Objective:

This study aims to determine the error rate particular to our department located in the commercial center of South Africa, and to uncover potential causes for discrepancies in radiological reporting between afterhours registrar opinions and those of qualified consultants. We aim to determine if workload, level of training, indication for CT scan, time of reporting, or body region scanned played a role in the error or discrepancy rate and what error types predominate.

2.0 Material and Methods

2.1: Study Design:

A prospective descriptive study was undertaken in two major referral hospitals affiliated to our department (Charlotte Maxeke Academic Hospital and Chris Hani Baragwanath Hospital) in Johannesburg, South Africa. Both are level one trauma centers. Afterhours registrar reports were evaluated over a 2 month period (1 month and 8 days collection period for Charlotte Maxeke Academic hospital and 1 month collection period for Chris Hani Baragwanath Hospital) from the beginning of May to the end of June 2010.

2.2 Current Practices:

Afterhours calls in our radiology department are covered by the registrar body. Calls are divided into senior and junior calls. Senior calls constitute covering CT in addition to ultrasound, interventional procedures and, infrequently, plain film or MRI reporting. Registrars enter the senior call rotation after approximately 12 months of training including three months of dedicated CT training, six months of fluoroscopy training, one month of interventional/angiography training, one month of ultrasound and one month of MRI training. Each hospital in the study was covered by a single registrar on senior call who remained on site for the duration of the call. At one hospital (Charlotte Maxeke Academic Hospital) registrars would start the call after a normal working day and leave the following morning while at the second hospital (Chris Hani Baragwanath) they would

start at 12pm and leave the following day at 12pm. In both cases registrars worked 24 hours.

Consultant radiologists in the department were available for advice telephonically or for assistance with interventional cases but they did not have remote access to images or any teleradiology capabilities.

2.3 Data Collection:

This study involved the use of the existing CT review process in place and formalizing data collection from this practice. Consultant radiologists reviewed the afterhours CT scans and were briefed as to what errors were considered to be major and which were considered to be minor based on the criterion of an error being potentially management changing or not. They were, however, also advised to use their own discretion in classifying errors as major or minor if, for example, they thought an error to be serious despite not being potentially management changing. Consultants were not blinded with regards to the registrar whose scans they were reviewing as clinical implications of feedback and follow-up had to be considered. Any changes to the provisional registrar report were noted in an amendment while major errors were communicated to the referring physician telephonically.

Information about each call period was collected. This included the year of training of the registrar on call, the total amount of scans done during the call period and a breakdown of the amount of scans done between certain time periods. The amount of major errors and

minor errors including the time they occurred, the indication for the scan (emergency or elective and trauma or non-trauma) and the type of error made (missed finding, misinterpretation, study design problem, wording of report and additional differential diagnosis needed) were also collected.

For the workload comparison each call period was assigned to one of three groups (low, medium or high workload) of approximately equal numbers. The low workload group comprised call periods with 17 or less scans per call, the medium workload group comprised call periods with between 18 and 23 scans per call and the high workload group comprised call periods with 24 or more scans per call period.

All radiology registrars on the senior call roster at the surveyed hospitals were included in the study. A number of registrars were however excluded as they had passed their final ('board') exams and their afterhours reports were not reviewed. Some study days were excluded due to technical errors and CT workstation malfunction.

2.4 Statistical Analysis:

Statistical analysis was performed by determining error rates for each of the various groups. These results were tested for significance using a two by two chi square analysis between each of the groups. The mid-p exact value was used to determine significance. In addition a generalized linear regression model using a Poisson link for the error rates for workload and year of training was performed to determine any significant interaction between these variables. A p value of < 0.05 was considered significant.

Ethical clearance from the University of the Witwatersrand was obtained prior to the study commencing.

Published literature was reviewed and calculations were extrapolated from the provided data to obtain comparable results for certain variables, such as workload, and where necessary, these data and results were rounded off.

3.0 Results

3.1 Overall:

1477 scans from 1154 patients were reported by a pool of 28 registrars on the senior call rotation. 90 call periods were considered for inclusion and comprised 40 weekend calls, 2 public holiday calls and 48 weekday calls. 10 of these call periods were excluded from the study, 6 because the registrars on call had passed their exams and thus their cases were not reviewed the following day, 2 for incomplete data collection, 1 due to a CT workstation error in which only the hard copies of the scans could be reported on and 1 as the registrar on call fell sick and a second registrar was needed to complete the calls. This left a total of 80 call periods for the study. An overall error rate of 17.1% comprising a major error rate of 7.7% and a minor error rate of 9.4% was found. An average of 18.5 scans (14.4 patients) were reported per night.

3.1 Error Type:

Missed findings made up the bulk of the errors (57.3%) (Fig. 1–5) followed by misinterpretations (32.0%) (Figs. 6 and 7). 4.3% of errors related to wording of the report and 2.8% involved incorrect CT study design (Fig. 8). The remaining 3.6% of errors were lack of adequate differential diagnoses.

3.2 Workload:

The low workload group (less than 17 scans per call) comprised 530 scans. The medium workload group (18 to 23 scans per call) had a total of 515 scans while the high workload group (greater than 24 scans per call) contained 432 scans. An overall error rate of 17.4%, 21.4% and 11.8% was noted for the low, medium and high workload groups respectively (Table 1). As all the workload groups contained high number of scans in comparison to comparable literature with only one call period in which there were less than 8 scans per call the association between workload and error rate was tested using a generalized linear model. This was found to be significant with p=0.038 (Fig. 9).

Table 3.1: Analysis of error rate by workload

Workload	**Total Scans**	**Number of Errors**		
		Total	**Major**	**Minor**
Low (0-17 scans)	530	92 *(17.4%)*$^{*\#}$	43 *(8.1%)*	49 *(9.2%)*
Medium (18-23 scans)	515	110 *(21.4%)*$^{*\$}$	50 *(9.7%)*	60 *(11.7%)*
High (> 24 scans)	432	51 *(11.8%)*$^{\#\$}$	20 *(4.6%)*	31 *(7.2%)*

* p = 0.0450
$^{\#}$ p = 0.008
$^{\$}$ p = 0.000

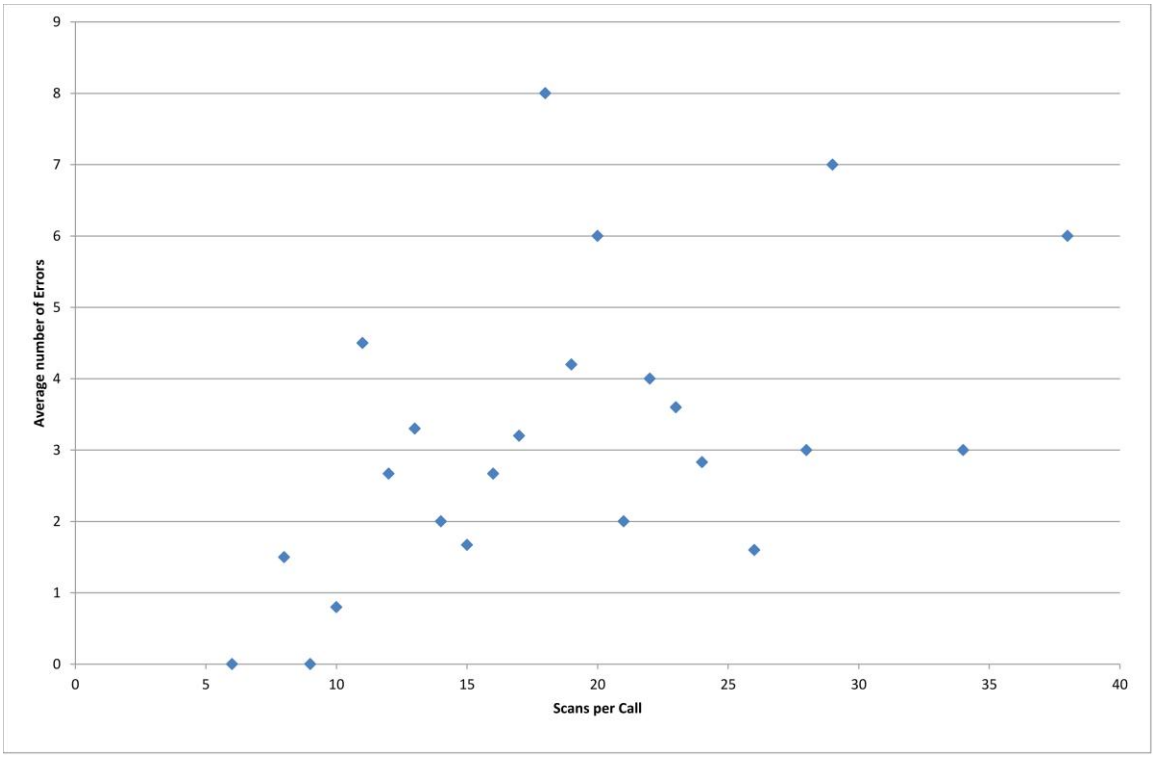

Figure 3.1: Scatter graph of the average number of errors per number of scans per call.

p=0.038

3.3 Year of Training:

Of the 80 call periods in the study, 37 calls (710 scans) were performed by year 2 registrars, 38 calls (684 scans) by year 3 registrars and 5 calls (83 scans) by year 4 registrars. Year 2 registrars fared worse than year 3 registrars with an error rate of 19.4% compared to 15.1% while year 4 registrars performed the best with an error rate of 14.5% (Table 2). The workloads for the different years were similar with an average of 19 scans per call for 2nd year registrars, 18 scans for 3rd year registrars and 16.6 scans per call for 4th year registrars. Comparison of the groups showed the only statistically significant difference was between the year 2 and year 3 registrars with a p =0.015. Comparison

using a generalized linear model between the groups was however not significant with p=0.069.

Table 3.2: Analysis of CT readings according to year of training

Year of Training	Total Scans	Number of Errors		
		Total	Major	Minor
2	710	138 (*19.4%)**	67 (*9.4%)*	71 (*10.0%*)
3	684	103 (*15.1%)**	41 (*6.0%*)	64 (*9.4%*)
4	83	12 (*14.5%)*	7 (*8.4%*)	5 (*6.0%*)

* p = 0.015

3.4 Body region scanned:

Analysis by body region scanned revealed that registrars fared far worse with abdominopelvic and chest CT scans (33.9% and 21.1% error rate respectively) followed by head CT scans with an error rate of 16.5% (Table 3). A statistically significant difference was only found between abdominopelvic and head scans (p = 0.003) and abdominopelvic and cervical/thoracic and lumbar spine scans (p = 0.000).When errors were classified as head or body scans we found a major error rate of 7.3% for head scans and 13.5% for body scans and an overall error rate of 16.5% for head and 28.4% for body scans. No significant difference was found with this comparison.

Table 3.3: Analysis of CT reading errors according to body region scanned

Body Region	Total Scans	Number of Errors		
		Total	Major	Minor
Head	904	149 *(16.5%)**	66 *(7.3%)*	83 *(9.2%)*
C/T/L Spine	273	32 *(11.77)*#*	17 *(6.2%)*	15 *(5.5%)*
Neck	49	6 *(12.2%)*	0 *(0%)*	6 *(12.2%)*
Chest	95	20 *(21.1%)*	7 *(7.4%)*	13 *(13.7%)*
Abdominopelvic	127	43 *(33.9%)*#*	23 *(18.1%)*	20 *(15.7%)*
Limbs	29	3 *(10.3%)*	1 *(3.4%)*	2 *(6.9%)*

* $p = 0.003$
# $p = 0.000$

3.5 Indication for scan:

Trauma scans accounted for 56% (828) of the total scans and 93.7% (1384) were emergency (including trauma) scans. The error rate for trauma vs. non trauma scans was found to be 15.6% vs. 19.1% respectively while the error rate for emergency scans vs. elective scans was 16.8% vs. 22.6% respectively (Table 4). There was a significant difference in the error rate between trauma and non-trauma scans (p =0.044) but not for emergency vs. elective scans (p = 0.085). The difference between the major error rate for trauma (6.9%) vs. non-trauma (9.6%) scans was found to be even more significant than the overall error rate (p = 0.010).

Table 3.4: Analysis of CT reading errors according to the indication for scanning

Scan Indication	Total Scans	Number of Errors		
		Total	Major	Minor
Trauma	822	130 (*15.8%*)*	52 (*6.3%*)#	78 (*9.5%*)
Non Trauma	645	124 (*19.2%*)*	62 (*9.6%*)#	62 (*9.6%*)
Emergency	1374	232 (*16.9%*)	107 (*7.8%*)	125 (*9.1%*)
Elective	93	21 (*22.6%*)	7 (*7.5%*)	14 (*15.1%*)

* $p = 0.044$
# $p = 0.010$

3.6 Time of scan:

Time of scan revealed an error rate of 14.9% for daytime scans, 20.1% for scans on call up till 22H00, 14.5% for call scans between 22H00 and 02H00 and 17.1% for scans reported on call after 02H00. No significant difference was found on analysis of these different groups but when comparing scans done between the start of the call period and 22H00 and the other three time periods combined there was a significant difference (p=0.008).

3.7 Example of errors

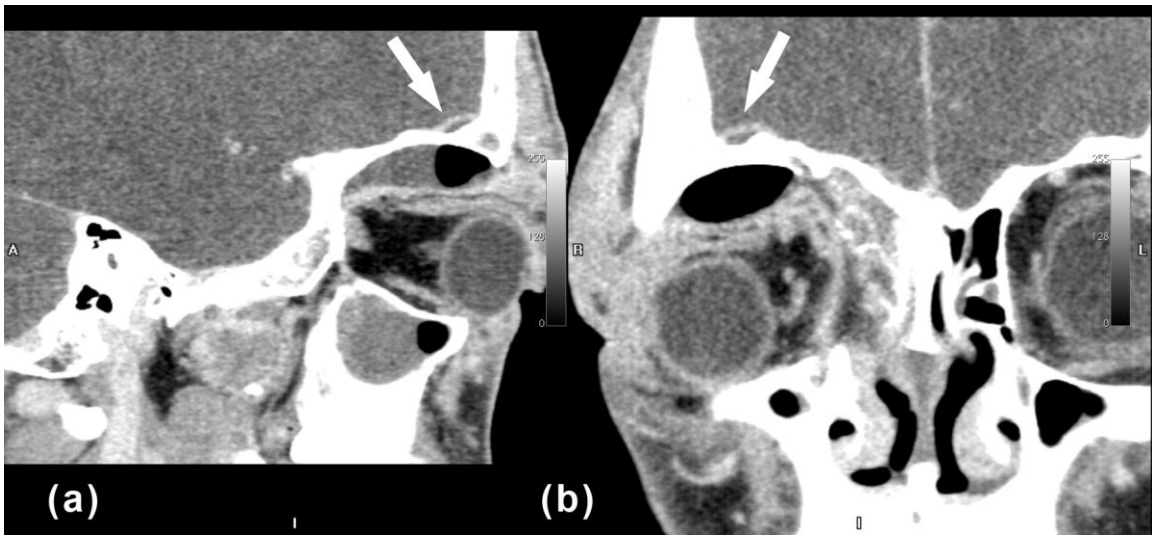

Figure 3.2: Major error in a CT scan of a Head.

Sagittal (a) and coronal (b) reconstruction on a post contrast CT scan of the head in a patient with periorbital cellulitis and sinusitis clinically. The extradural collection (arrow) in the anterior cranial fossa complicating the infective sinusitis and periorbital abscess was missed.



Figure 3.3: Minor error in a post-contrast CT scan of an abdomen.

Axial post contrast CT scan of abdomen demonstrates hypo-dense liver lesions which were an incidental finding missed by the reporting registrar in a patient with trauma. These lesions filled in on the delayed images (not shown) and were diagnosed as haemangiomas of the liver by the reviewing consultant.



Figure 3.4: Major error in a pre-contrast CT scan of the C-spine.

Axial pre-contrast cervical spine CT scan performed for trauma demonstrates a comminuted fracture of the distal right clavicle which was missed on the registrar report.

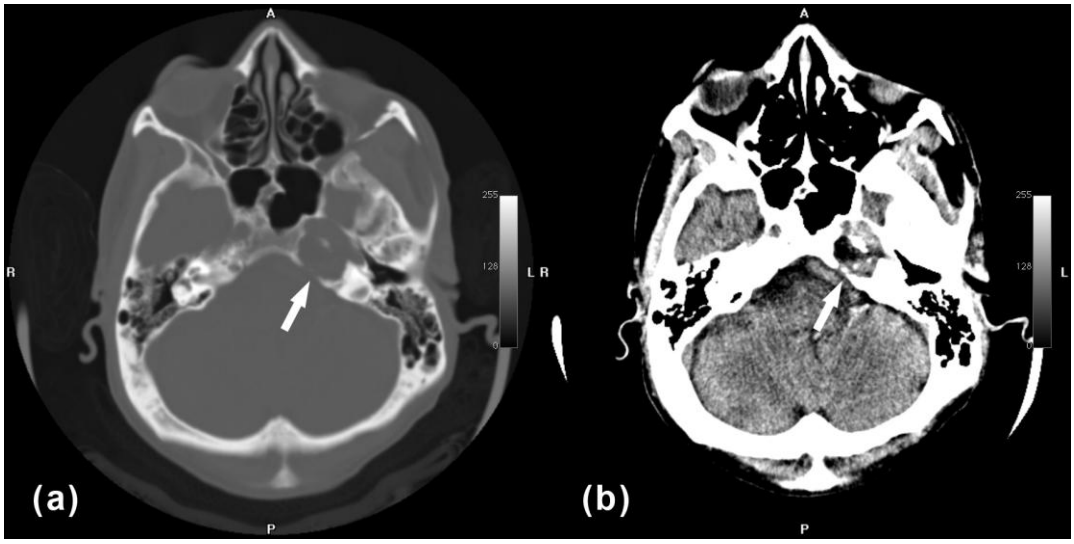

Figure 3.5: Major error in a pre-contrast CT Brain.

Axial pre contrast CT scan in a 45 year old male involved in trauma. Bony (a) and soft tissue (b) windows demonstrate a soft tissue mass with accompanying bony erosion involving the left petrous apex. This was missed by the registrar on call.

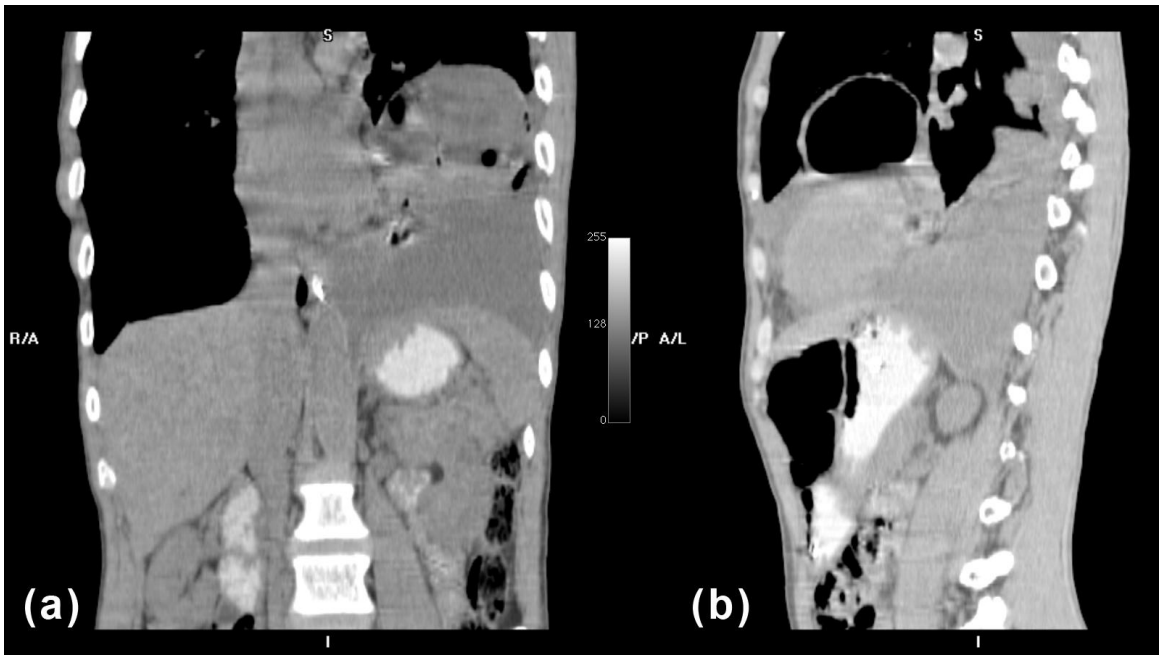

Figure 3.6: Major error in a post contrast CT abdomen.

Coronal (a) and sagittal (b) reconstructions of a 56 year old trauma patient in which the diaphragmatic hernia was missed.

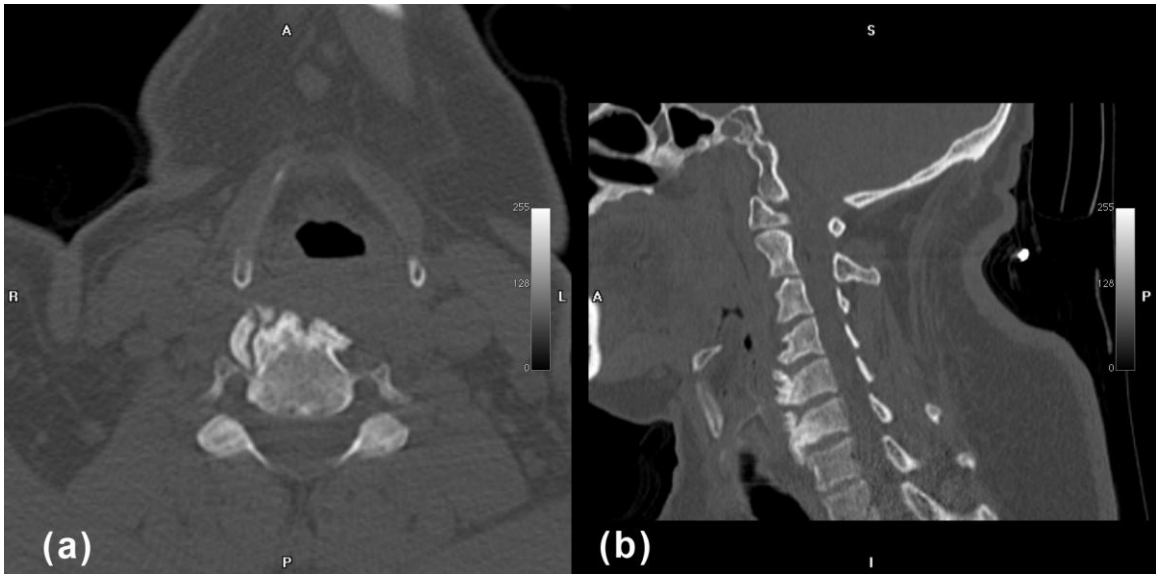

Figure 3.7: Major error in a pre-contrast CT C-spine in trauma.

Axial (a) and sagittal reconstruction (b) of a 53 year old male patient post head trauma. The degenerative changes seen in the C-spine were misinterpreted as vertebral body fractures

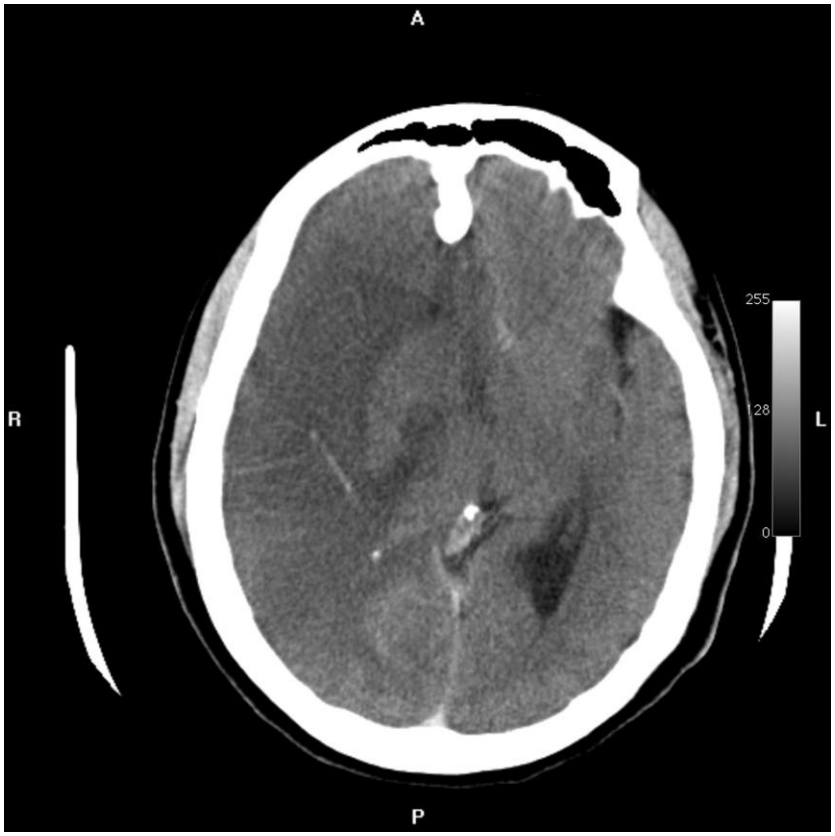

Figure 3.8: Major error in a non-contrast CT brain.

Axial non-contrast CT scan of the brain in a patient with decreased level of consciousness. There is a right sided middle cerebral artery territory infarct seen with local mass effect and cerebral edema. Perfusion is maintained to the right basal ganglia. The relative density of the right basal ganglia in comparison to the infarcted tissue was misinterpreted as a hypertensive bleed.

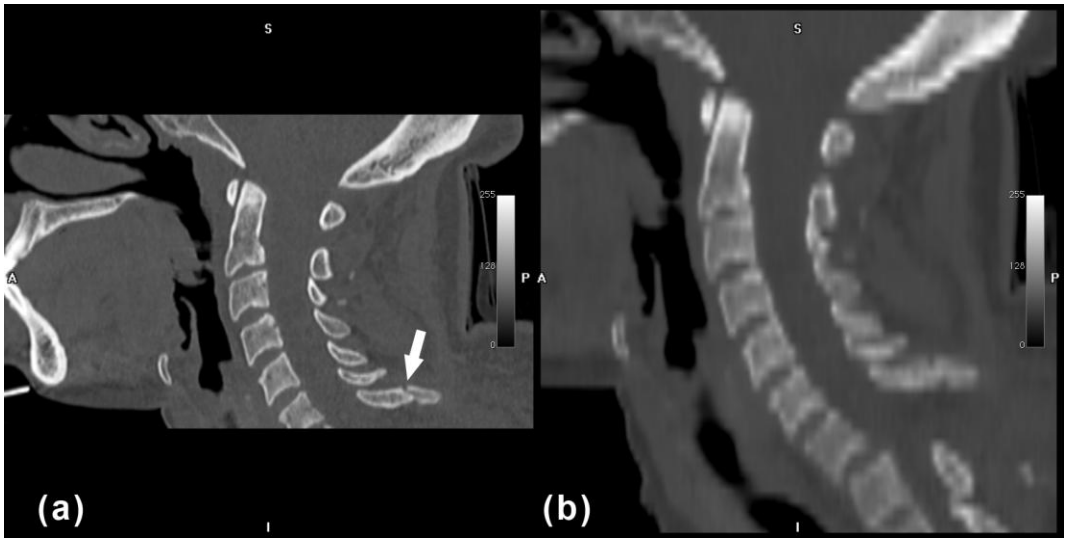

Figure 3.9: Major error in a precontrast CT C-spine in trauma.

Sagittal reconstruction (a) of a non-contrast CT scan of the cervical spine in a 35 year old female trauma patient is inadequate only extending to the inferior border of C6. This was reported as a fracture of the spinous process of C6. Thick slice reconstruction (b) was performed from the available data by the consultant reviewing the case the following morning and bilateral perched facet joints of C7 on T1 were diagnosed. This was confirmed on repeat CT scan.

4.0 Discussion and Conclusion

Velmahos et al makes the point that trauma normally happens afterhours and "fast decisions must be made in a precise and timely manner" (6). This is likely the case for non-trauma emergency patients as well who require prompt and accurate interpretation of imaging studies. CT scans are best interpreted by a radiologist as it has been shown that emergency physicians with no formal radiology training have low specificity and sensitivity for interpreting trauma head CT scans (7). Our study revealed an overall error rate of 17.1% which is higher than most of the comparable studies in the literature which focus on emergency scans (1,4,6,8,9), yet lower than that shown by Hillier et al in their study on elective scans (10). The difference in discrepancy rates suggests that more errors are made when reporting elective CT scans as opposed to emergency scans, likely due to the increased complexity of elective cases. Our study did not confirm this difference in error rates between elective and emergency scans as the *p* value was not significant (p=0.085) which may in part be due to a low sample size for the elective scans (n=93). This association should be tested with more balanced sample sizes. When looking at error rate differences between trauma and non-trauma scans we did find a significant difference between the two (p=0.044) which was more pronounced when we selected out the major errors only (p=0.010). One possible explanation for this decrease in error rate when reporting trauma scans is the routine increased exposure to trauma scans received by registrars on after-hour calls. Polytrauma scans have however been reported as having a registrar error rate as high as 24% although only 4% of these errors were deemed major (11). We have no specific data available specifically regarding polytrauma compared to simple trauma scans but further studies in this regard are warranted.

Our study had an average of 18.5 scans per call period. All but one of comparable studies had less than 8 scans per call (Table 5). Our results showed only one call period with less than 8 scans making direct comparison difficult. We did however find, as expected, an increasing error rate with increasing numbers of scans per call when using the generalized linear regression model. The high workload group however had a low percentage of errors compared to the other groups. We surmise this to be due to error during the reviewing process by consultants. As this study was set up to mirror the daily departmental workflow consultants reviewed the cases from the previous call period during normal working hours between reporting new cases. With very heavy call periods this review process was likely suboptimal and errors in the registrar report may not have been noted by the consultant. We also found a significant difference between the time periods for reporting. We found that when the reporting period from the beginning of the call until 22h00 was compared to the rest of the reporting periods combined there was a significant difference (p= 0.008). We felt this finding likely reflects an effect of workload rather than the timing of the scan report. At both hospitals in this study there are normally between 5 to 25 patients left over from the day list that need to be scanned and reported during the call. The majority of these scans will occur before 22H00 and therefore this is the busiest workload period with the highest amount of scans per hour. For this reason we feel the findings comparing these groups according to time period of CT scan most likely reflect a workload phenomenon. As we did not design this particular peculiarity into the study we suggest further studies to evaluate this apparent finding. Davenport et al showed

that caseload had the greatest effect on discordance rate between resident and attending radiologists report (12).

Radiology, as with all medical disciplines, requires experience to master. It would be assumed that junior registrars and residents make more interpretation errors than their senior counterparts, an assumption supported by a number of previous studies (2,4,5,6,8,9,10). Some of these studies show an increase in error rate after the 2nd year of training before a decrease again in the later years (2,9). This seems to be partly due to decreased amount of time on call and paring up of juniors with more senior trainees. Our study shows a statistically significant decrease in the overall error rate from 2nd to 3rd year registrars but no overall difference between all the groups. There was however an increase in the major error rate between the 3rd and 4th year registrars although this was not found to be significant. As 4th year registrars are about to sit their final exams their reports are likely scrutinized more intently by reviewing consultants and minor errors may be deemed 'radiolically major' accounting for the increase noted above.

Abdominopelvic scans were found to have an error rate of 33.9%, significantly more than head scans (16.5%) and C/T/L spine scans (11.7%). The rest of the body regions studied had a lower error rate but no statistical difference was found, possibly due to the lower numbers of these scans. The error rate for abdominal scans is markedly out of keeping with error rates of comparable research studies with the exception of the study by Tieng et al who also looked at 'body scans' although no specification was made as to whether these were abdominopelvic or thoracic scans (13). Other research studies looking at body

scans found lower error rates of 21.5% (10) and 9.8% (5) than those in our study but still higher than those research studies dealing with only head scans. It follows that body scans are more complex and create more problems for the trainee to report. When coupled with the stress of being on call alone the error rate escalates.

Comparable studies have found between 69% and 92% of discrepancies to be related to missed findings (false negatives) (4,10). Our results are in keeping with these studies with 57.3% of errors related to missed findings, by far the majority. This is likely a combination of registrar inexperience coupled with an extremely high workload and resultant time pressure to report waiting scans. Study design problems, while small in number, prove to be difficult to rectify as often the patient is already discharged resulting in the need to trace them for repeat imaging. Misinterpretation of findings and additional differential diagnoses required are a function of academic training and further study is required in this regard to determine potential remedies for these errors.

There are a number of limitations in our study design. The criteria for a consultant to determine a major from a minor error was based on individual opinion of whether the finding could be considered management changing or not as opposed to actual patient follow up. A relatively short period was sampled and reviewing radiologists were not blinded to the registrar who was performing the study which may introduce bias. These shortcomings were unfortunately largely unavoidable owing to the practicality of conducting the study without disruption to the departmental workflow and the high workload both during the day and at night.

In conclusion, we found a significantly high error rate with registrars reporting of abdominopelvic scans compared to other body regions. We also noted a marked improvement from 2nd year to 3rd year registrars and a significantly lower error rate when reporting trauma scans compared to non-trauma scans. Workload appears to play a large role with a significant increase in errors between with increasing workload as well as an increase in errors in the early evening reporting time period where workload is at its most intense. The unexpected drop in error rate in the highest workload category we feel reflects the shortcomings in the reviewing process the following day again related to the high caseload.

Based on this study our institution has now changed the registrar call system from a single registrar on call to one with two registrars on call together, a more senior registrar paired with a junior registrar. A re-evaluation of this system once established may show the effects of such an intervention.

Table 4.1: Summary of findings of relevant literature compared with our results

		Number of Cases /Scans	Collection Days	Average number of cases per period	Discrepancy Rate			Year of training	Body Region	Scan Indication
	Year				Overall	Major	Minor			
Chung J (4)	2009	4768	801	6.0	2.0%	-	-	3,4	body	emergency
Cooper VF (5)	2008	48249	2646	18.2	-	1.4%	4.9%	1,2,3,4,5	head	emergency
					-	2.5%	7.3%	1,2,3,4,5	body	emergency
Roszler MH (1)	1991	289	60	4.8	4.2%	2.0%	2.0%	2,3,4	head	emergency
Wysoki MG (9)	1998	419	516	0.8	5.2%	1.7%	2.6%	1,2,3	head	trauma only
Hillier JC (10)	2003	331	182	1.8	21.5%	10.0%	11.5%	3,4	body	elective
Tieng N (13)	2006	203	28	7.3	29.5%	10.0%	20.0%	3,4	body	emergency
Velmahos GC (6)	2001	699	181	3.9	6.0%	2.9%	3.2%	2,4	all	emergency
Carney E (8)	2003	513	180	2.9	-	5.4%	1.0%	1,2,3,4	body	emergency
Our Study	**2010**	**1477**	**80**	**18.5**	**17.1%**	**7.7%**	**9.4%**	**2,3,4**	**all**	**all**

Appendix

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