Can retrospectively fusing SPECT to CT images reduce radiation doses in myocardial perfusion imaging?

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Abstract

Introduction: To establish if the CT data set acquired during the stress element of myocardial perfusion imaging can be fused to the subsequent rest scan to reduce radiation doses from these procedures.

Methods: 86 rest scans were processed and evaluated using a self- designed project specific tool. Recording processing time, the time between the two data sets selected for fusion and assessing radiographic reports to ensure produced images were of diagnostic quality.

Results: 70% of fused scans were acquired 6-7 days apart; the average processing time was calculated as 2.03 Minutes. The Pearson's correlation between these two variables was determined to be 0.222775, showing a slight positive correlation although not statistically significant. 100% of the images produced were of diagnostic quality this is partly attributed to departmental procedures.

Conclusion: Rest scans can be fused to a previously acquired CT, careful consideration should be given when positioning the patient and to the time interval between acquiring the two data sets, departmental guidelines can assist with this. Staff training may also be beneficial to ensure staff can assess if data sets are fusible prior to completing a scan.

Implications for practice: This data provides evidence that retrospective fusion can reduce patient radiation doses in myocardial perfusion imaging without compromising diagnostic outcomes. Dose optimisation is an essential part of the ionising radiation (medical exposure) regulations therefore retrospective fusion should be considered in practice to ensure departmental compliance, although

it is noteworthy this study is solely based in a single centred one camera department.

Keywords

MPI, Retrospective Fusion, Attenuation Correction.

Introduction

The collective radiation dose from nuclear medicine procedures has increased by a factor of 8 from 1984-2006 [1] Reasons for this include; a tripling in the amount of procedures undertaken, the establishment of higher dose procedures and the implementation of hybrid imaging [1].

Gamma radiation and x-rays are forms of ionising radiation which can cause stochastic and deterministic effects [2]. Ionising Radiation Medical Exposure Regulations (IR(ME)R) (2017) [3] stated that dose optimisation should be integral to ensure doses are kept as low as reasonably practicable. Departments have a duty to patients to adhere to these regulations.

When utilised the CT component of a hybrid gamma camera provides an additional associated radiation dose burden. Hybrid gamma cameras are available with either diagnostic quality CT scanners or low- resolution CT scanners. If the CT is solely for attenuation correction purposes, the relevant scan parameters should be reduced to provide a scan fit for purpose whilst delivering minimal radiation dose to the patient.

Myocardial perfusion imaging (MPI) is used in the diagnosis of coronary artery disease, to determine a patents risk of a cardiac event and aid with patient management [4]. MPI can consist of two scans, a stress and a rest. In 2012, MPI was estimated to contribute to 20% of the annual collective radiation dose from diagnostic procedures within the United States [5]. Attenuation correction can be applied as part of stress and rest scans by acquiring a CT scan.

Attenuation correction increases diagnostic confidence of MPI by providing the ability to correct for artefacts caused by different anatomical structures surrounding the heart. These different density structures can lead to attenuation defects which could be perceived as perfusion defects and then provide the incorrect diagnosis [6]. Thus, justifying the use of attenuation correction and the additional radiation dose burden.

Genovesi et al (2011) [4] recommended that by utilising modern cardiac processing software there is potential for a 50% reduction in CT radiation doses within MPI by utilising the stress CT dataset for rest image processing, this could be a reduction of 0.25-0.45 mSv.

A factor to consider prior to determining the appropriateness of retrospective fusion is the time frame between the desired examinations to be fused. If excessive there may be changes to the condition which will not be present on both datasets and could mislead the report. A further consideration is patient positioning may differ if different operators are involved; this can result in organ movement which is difficult to compensate for when undertaking image fusion [7]. To minimise this, it is desirable for the patients to be scanned in as similar a position as possible. It is noteworthy that both acquisitions are never able to be acquired truly simultaneously due to long SPECT acquisition times this results in differences in respiratory phases and cardiac motion, therefore care must always be taken during software co-registration to ensure accurate fusion is employed including on occasions when both datasets are acquired in the same appointment [8] .

The consequence of poor image fusion in anatomical localisation studies is that misaligned datasets, if unnoticed, can cause diagnostic error dependent upon the magnitude of inaccuracy and type of study. If the main use of the CT dataset is for attenuation correction the error may not be obvious but will still be misleading [7]. With misaligned datasets resulting in false perfusion defects [6].

Previous studies have shown optimistic yet not definitive results regarding the possibility of utilising one CT scan for image fusion to both the stress and rest studies within MPI [9]. By eliminating the requirement for a second CT scan radiation dose from these procedures can be reduced. As there are currently no national guidelines available and limited research to justify current departmental practice it was deemed appropriate to evaluate the current departmental practice of retrospectively fusing images for MPI.

This study aims to:

1. Assess if rest scans can be retrospectively fused to stress CT datasets to produce images of diagnostic image quality.
2. Determine whether image fusion can be utilised to reduce patient radiation doses from MPI procedures.
3. Assess if long time intervals between stress and rest scans results in more challenging/inaccurate image fusion.
4. Ensure retrospective fusion is practicable for every day working within a nuclear medicine department.

Method

Current departmental practice entails a 2-day stress rest protocol following administration of the stressing agent Regedenason and Tc^{99m} Sestamibi. SPECT acquisition begins at 45-60 minutes following radiopharmaceutical injection. Images were acquired using GE NM optima 640, with a 64 × 64 matrix for the emission images. A total of 30 emission, transmission and scatter projections were obtained at 30-seconds/projection. These conditions are the same for stress and rest SPECT acquisitions, gating is also applied.

CT images are acquired immediately following stress acquisition, using 120 KV and 20mA with a slice thickness of 2.5mm, a rotation time of 1 second and helical pitch of 1.25. No CT is obtained following rest acquisition.

Attenuation-corrected transverse images were reconstructed by prefiltering the emission a Butterworth filter with a critical frequency of 0.57. The motion correction algorithm was implemented if required based on cine image assessment. Rejected beats are checked to ensure the gating was effective and attenuation maps are generated by checking the computer-generated maps and manually amending the alignment of the emission data with the anatomical CT scan.

A data collection tool (Table 1) was designed specifically for this study, there were no established tools available.

Processing time is deemed to be directly proportional to processing difficulty. Scans which are more difficult to process could result in an increased likelihood of processing error as well as being unpracticable for departments whereby processing stations and staff are a limited resource. Therefore, it was deemed desirable to further assess the relationship between these two numerical data sets by undertaking a Pearson's correlation. To enable this statistical analysis a power calculation was performed to determine the appropriate sample size. The power calculation (Figure 1) recommends a sample size of 86 as optimal. The priori calculation was based on a power of 85% which is deemed as good practice and ensures an acceptable margin of reliability [14].

Diagnostic quality image assessment and radiation dose saving will be based on the content of the issued report. Reports should comment on whether a study was undiagnostic or if any further imaging is required [10]. A simple percentage of yes/no responses will be generated, a purposive sample was deemed appropriate therefore 86 scans were deemed sufficient.

The inclusion criteria established became the previous 86 MPI examinations from 18 February 2020. This will reduce bias as scans are not "selected" for this study. There is no need to recruit participants as this is an evaluation of current departmental practice, i.e. only patients who require retrospective fusion as part of their procedure are included.

Ethical Considerations

Informed consent is gained prior to any nuclear medicine procedure in line with departmental protocol. All patients have a discussion with the operator prior to the procedure to ensure consent for the examination is obtained. No identifiable data was collected therefore participants were not required to be contacted to obtain additional consent.

In line with Health Board protocols the study underwent an organisational review prior to commencing to ensure there are no potential ethical issues going forward into the data collection phase. UWE ethics committee also reviewed and approved the study.

Results

A wide variation in time intervals between the stress/CT and rest scan acquisitions were recorded, these are demonstrated graphically in figure 2 . The longest time interval between the two acquisitions was twenty-one days with the shortest at one day. A majority i.e. 72% of cases had a time interval of six to seven days between the two acquisitions required for fusion.

The average processing time for image fusion was calculated as 2.03 minutes. A test case was additionally undertaken to assess the standard processing time for a study which had required two separate CT scans, the processing time of this test case was deemed to be 1.21 minutes. This is a difference in average processing time compared to the test case of 42 seconds.

Figure 3 illustrates the relationship between processing time and time interval between acquiring the CT dataset and the rest dataset for each patient within the sample. The Pearson's correlation was calculated and is determined to be 0.222775.

100% of reports determined that images were of diagnostic quality and no patients were recalled for repeat imaging. Subsequently it can be ascertained that 100% of patients achieved a radiation dose saving by utilising the previously acquired CT dataset.

Discussion

An average interval of six to seven days between the two acquisitions is representative of current departmental practice. The BNMS (2012) [11] advocate a two-day protocol due to superior image quality and a lower required radiation dose, as a result this is the departmental preference, however the BNMS (2012) [11] did not provide guidance as to how long is acceptable between stress and rest scans . In addition to this IR(ME)R (2017) [3] emphasises the need to avoid unnecessary radiation exposure; in relation to MPI this has been interpreted by the department as needing to minimise excessive rest scans. Consequently, stress scans are processed then reviewed by a Consultant Cardiologist prior to rest scans being appointed, this can result in a delay to rest scans being acquired. Chang et al (2010) [12] approved of this practice despite the slight delay, following a study of over 16,000 MPS. The minimal delay required for stress scans to be reviewed was deemed to have negligible effects on patients' overall outcomes but provide a vast dose saving.

It is noteworthy that some patients had a significantly shorter time interval, these patients were inpatients. In accordance with national diagnostic imaging board (2008) [13] inpatients need to be reported on the same day and therefore were reviewed as soon as practicable and rest scans performed at the earliest possible occasion. Those studies with a longer time interval tended to be due to circumstances beyond the departments control i.e. patient availability.

With increasing imaging demands processing time is a valuable resource, if processing time is overly excessive this may not be practicable to implement. The test case was deemed a desirable undertaking for comparison. The test case includes two CT scans, one at stress and an additional CT dataset at rest. These integrated studies are normally fused via a computer algorithm; however, they still require checking by an appropriate operator to avoid potential misdiagnosis [6]. The difference between the average processing time for image fusion and the time required to check computer algorithm processing of the integrated test case was deemed to be feasible within clinical practice.

There is a slightly positive Pearson's correlation although not deemed statistically significant i.e. those studies with a longer time interval took slightly longer to process. However as discussed earlier a majority of the sample had a similar time interval rather than a widely distributed sample due to departmental practices. Although the sample size was deemed to provide a statistically significant result when calculated the limited distribution i.e. less than 20% of the sample having a time interval greater than seven days could have an impact on the significance of this result.

All images were deemed to be diagnostic quality based upon analysis of the finalised reports, however the same limitations to sample size apply as above. This result validates the current departmental protocols in relation to acquiring the one CT imaging component in MPI. Current practices aimed at minimising any impacts of the potential pitfalls outlined in the background are successful. All operators are aware of the standard patient position and the department requires any differences to this position are documented on the request form during the stress acquisition, this process allows the operator who undertakes the rest scan to ensure the same amendments are made. Finally, as previously discussed the smallest time interval practicable is utilised when appointing rest scans to minimise the effects of anatomical/pathological changes.

As a result of all images produced being of diagnostic quality it can be determined that all patients therefore received a radiation dose saving by acquiring one CT dataset rather than two. The current national diagnostic reference level for the CT component of myocardial perfusion imaging is a DLP of 36 mGy-cm. The local diagnostic reference level is significantly lower than this limit due to the low-resolution CT component of the hybrid gamma camera within the department. The local diagnostic reference level is a DLP of 17 mGy-cm. The data collection process did not record each individual's CT so an accurate dose saving for each patient has not been obtained. An average dose saving is deemed to be comparable to the local DLP of 17mGy-cm which was generated by calculating the average CT dose from 20 MPI examinations.

Limitations

This study assessed processes within a single centre with one low-resolution hybrid gamma camera and one manufacturer's processing software. The processing software selected was GE Myovation, within the manufacturer handbook the ability to fuse one CT acquisition to both stress and rest datasets is mentioned and advocated as a method to minimise radiation dose, although a warning is provided over the possible consequences of inaccurate fusion. Different processing software may not have this capability or may yield different results. A further area of research would require multiple centres, a variety of manufacturer gamma cameras and different processing software's.

To ensure consistency and limit required resources in this study all processing was undertaken by one individual. This method reduced the generalisability of the study, due to the different skill sets, backgrounds, and level of training of different operators. A further area of research could also assess processing consistency between individuals.

Due to social distancing restrictions at the time of data collection, data was gathered outside of clinical hours, including image processing. These conditions differ to normal clinical environment, which could have had a result on processing times. These differences include reduced disruptions due to being the only individual within the department and no requirement for other clinical duties.

A further limitation identified was the use of MPI reports to determine the diagnostic quality of the scans. This study would benefit from further evaluation of patient outcomes following MPI imaging to determine if the imaging findings were accurate however this data was difficult to obtain in the time constraints of this research.

Conclusion

Diagnostic quality images can be produced by fusing previously acquired CT datasets from MPI stress studies to MPI rest datasets for attenuation correction without detriment to a timely efficient imaging service. The evaluation confirmed that current protocols in relation to patient positioning and minimising delays between scans are effective and doses are being optimised in accordance with current national IR(ME)R guidelines. Further research is needed to assess this in different centres and with different processing software.

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Figures and Tables

Figure 1

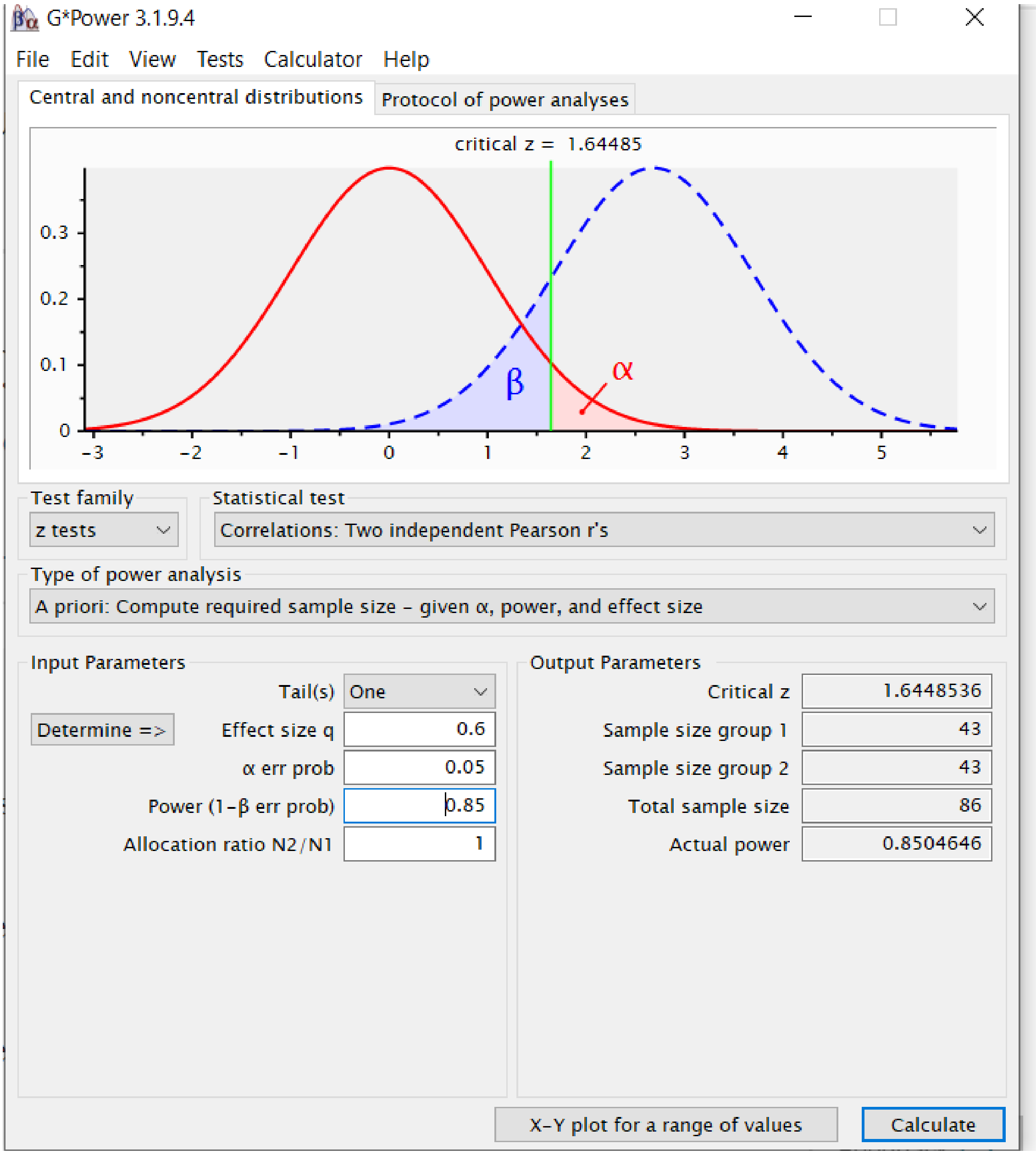
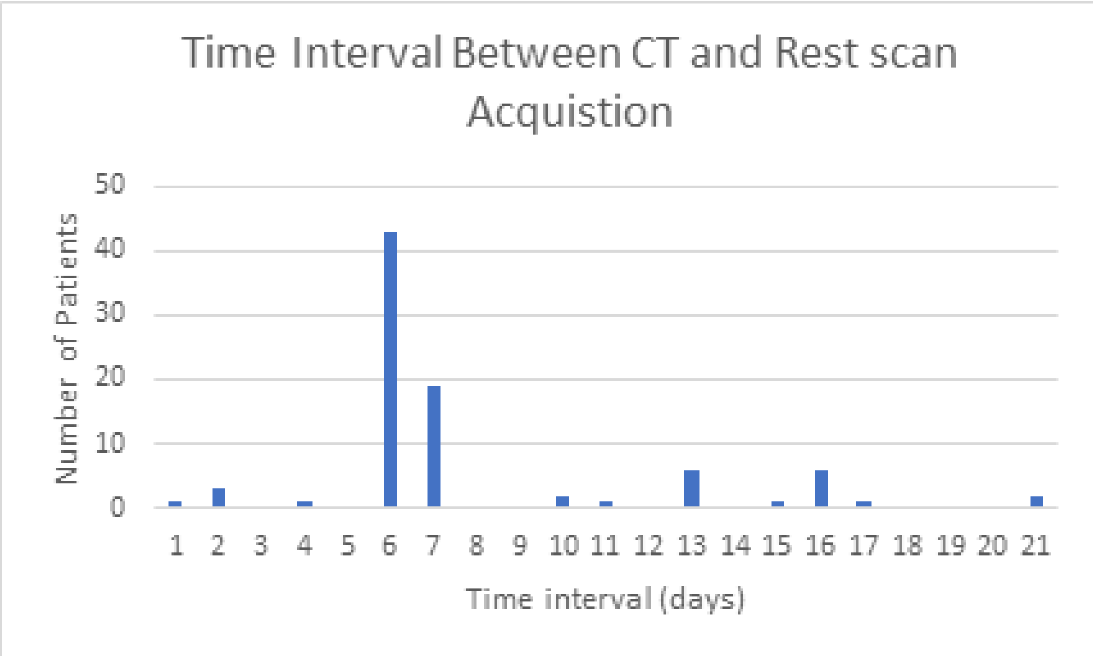


Figure 2



Time Interval Between CT and Rest scan Acquistion
50
40
30
20
10
0
Number of Patients
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Time interval (days)

Figure 3

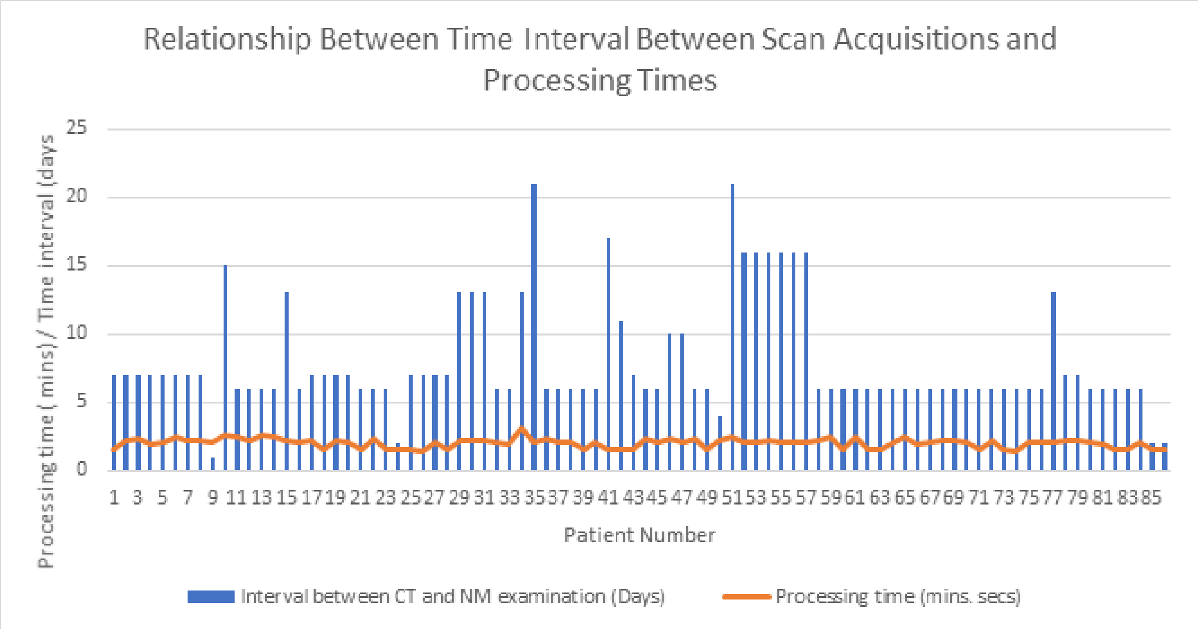

Relationship Between Time Interval Between Scan Acquisitions and Processing Times
Processing time (mins) / Time interval (days
25
20
15
10
5
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85
Patient Number
Interval between CT and NM examination (Days)
Processing time (mins. secs)

Table 1

Patient (1-86)	Interval between CT and NM (Days)	Processing time (Minutes)	Were images of diagnostic quality? (Yes/No)	Was there a radiation dose saving? (Yes/No)

Table 2

Patient Weight (Kg)	Activity (MBq)	Effective Dose (mSv)
<80	400	3.2
80-90	450	3.7
91-100	500	4.2
101-110	550	4.7
111-120	600	5.2
121-130	650	5.7
131-140	700	6.2
141-150	750	6.7
>150	800	7.2