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Review of Claustrophobia Incidence in MRI:

A service evaluation of current rates across a multi-centre service

Introduction:

Patient anxiety related to undergoing medical imaging procedures is common, with reported incidence varying from 49-95% (1,2). The source of this may be related to particular aspects of the procedure itself or anticipation of the significance of results (1–7). For Magnetic Resonance Imaging (MRI) the most notable response is one of claustrophobia due to the enclosing nature of the scanning equipment, along with scanning noise, duration and lying flat(8–10). A range of responses are reported, from awareness of discomfort to extreme panic(11), with heightened anxiety reported in 29-56% of patients (1,2,12) and up to 3.4 times more likely when compared to undergoing an ultrasound scan(1). This impacts patient outcomes; movement or reduced scan times may reduce scan quality (13–16) through to inability to tolerate or even attempt a scan(15,17–19). This then has financial and operational impacts on scanning units(13,19–21).

Meta-analysis has shown an incidence of 0.46-5.29% premature termination rate in MRI (summed effect 1.8%) with the potential for this to drop below 1% as scanner design improves (22). Indeed, it has been argued that as new designs and technological enhancements become commonplace, the need to consider claustrophobia related anxiety in MRI will be removed(23). Scanners are becoming more patient friendly by design, coupled with developments that reduce scan acquisition times(21,24–26).

However, studies have shown that as of 2017 in the UK over 50% of scanners were still traditional narrow bore (60cm) systems(27) and there has been no change in the percentage of scanners in practice over 10years old since 2015(28). As a consequence, it seems improbable that incidence of premature scan termination due to claustrophobia will show significant reduction whilst provision across the UK is not currently making available the benefits of newer technology to improve patient experience.

As well as the influence of scanning equipment, it would be advantageous to understand whether any specific patient groups may be more prone to an anxious response to their scan experience. This would enable services to tailor emotional support provided, an important element of person-centred care(29). Being able to offer reasonable adjustment for patients goes some way to addressing potential inequalities, where all patients should be appropriately supported to achieve the scan and diagnosis needed to inform their care.

Therefore, the aim of this evaluation was to provide a current view on the incidence of scan related anxiety, defined as failure to scan due to claustrophobia, drawing on operational data alone.

Specific questions to address were:

- What is the incidence of incomplete scanning as a result of claustrophobia in clinical practice, and how may common patient or examination factors influence this?
- Has there been an increase in anxiety, displayed as failure to scan due to claustrophobia, during the COVID-19 pandemic?

Methods:

Internal review and study approval was received by the organisations Clinical Quality Sub Committee and Director of Clinical Quality in March 2021.

Operational data from MRI appointments conducted between April 2019 and March 2021 were extracted from an internal data system (Kimera). Data available were from 156 site locations; including static, mobile, and outsourced third parties. The majority of services were for the National Health Service (NHS), both hospital or community based, with some private providers. Therefore, a wide range of examinations and patient types were represented across a UK footprint of services. Information available included scanner type, patient age, sex, anatomical scan area, attendance status, completion status and reasons for incomplete scanning. Those entries from the failure to scan data reported by the scanning radiographer as due to claustrophobia were captured.

No patient identifiable data were obtained for the study. Descriptive analysis of all data was performed in Excel for calculation of group sums, means and standard deviations. Statistical analysis was performed in SPSS (IBM v26). Association between the year quarter with scan outcome was assessed using Chi^2 analysis. A relationship between age and scan outcome was assessed using independent t-test. One-way ANOVA was used to investigate for differences between scanner types and the incidence of scan outcome. Binomial logistic regression was performed on the variables age, sex, scanner type, examination area, entry into scanner and funding to assess their value in prediction of the dichotomous outcome of scan success or failure due to claustrophobia.

Results:

Patient appointments reviewed from over the 2-year period totalled 677 988, with a summary of attendance outlined in table 1. Supplementary data provides further information regarding the geographical spread of sites, quarterly breakdown of attendance and claustrophobia over both years, as well as examination mix. There was a reduction in patient examinations during 2020/21 of 25%, with the overall incidence of claustrophobia rising by 0.1% and patients not attending (DNA) rising by 0.2%. Chi^2 analysis showed a statistically significant relationship between year and both

outcomes (p<0.001). However, the strength of association was extremely weak (Phi 0.005) and deemed insufficient to skew analysis, so whilst acknowledging this difference, data was aggregated for subsequent review to maximise the sample size and relevance to the current real-life setting.

Table 1: Reviewed appointment summary data

N (%)	**2019/20**	**2020/21**	**Overall**
Exams booked	385783 (57[±])	292205 (43[±])	677988
Exams attended	369520 (57[±])	279236 (43[±])	648756
Did Not Attend	16263 (4.2*)	12969 (4.4*)	29232 (4.3*)
Attended but incomplete	8524 (2.3*)	7290 (2.6*)	15814 (2.4*)
Incomplete due to claustrophobia	2562 (0.69*/32[+])	2354 (0.84*/30[+])	4916 (0.76*/31[+])

[±] *percentage of total exams*
** incidence rate (number/total)*
[+] *percentage of the incomplete exams*

Scanner Design

Binomial logistic regression showed a significant relationship between scanner design and the occurrence of claustrophobia abandonment (p<0.01 - table 2). When compared with a conventional design; those undergoing an open scan were found to be around three times more likely to have an incomplete scan due to claustrophobia, whilst those undergoing UpRight were half as likely to fail. Figure 1 provides an example of the scanner designs.

Figure 1: examples of scanner designs

Top Left - Conventional, horizontal bore scanner (60-70cm diameter). 1.5T in field strength. Patients are required to lie horizontal.
Bottom Left - UpRight scanner with 56cm gap side to side. 0.5T in field strength with examination limitations. Patients are able to sit or stand.
Right - Open Scanner with 44cm gap top-bottom. 1.2T in field strength capable of equivalent examination to conventional scanner. Patients are required to lie horizontal.

Images courtesy of InHealth Group and Shutterstock

Examination Type

A doubling in incidence of abandoned scans due to claustrophobia was noted when patients were scanned head first compared to feet first in conventional scanners (1.1% vs 0.5%). Binomial logistic regression indicates the odds of failing due to claustrophobia is approximately double when a patient enters head first ($p<0.001$ - Table 2).

The placement of receiver coils over areas of the body being examined adds an additional factor that can influence feelings of entrapment and restriction associated with claustrophobia. Comparing head and neck exams with those of the knee and below, suggests a statistically significant predictor

(p<0.001 - table 2), with a tenfold increase in incidence and eight times likelihood when scanning the former compared to the latter (1.1% vs 0.1% respectively).

Table 2: significant binomial regression outputs for occurrence of claustrophobic event

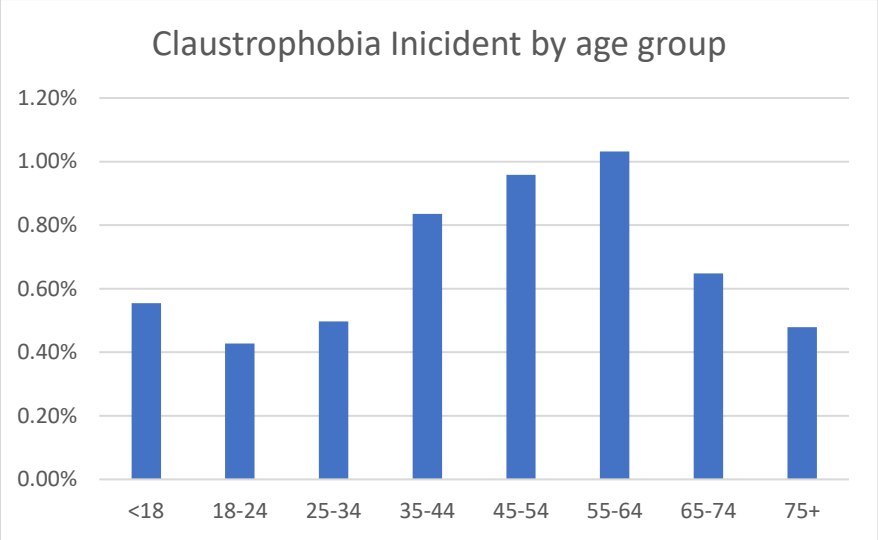
Category	Subcategory	Number (Failed claustrophobic / total attendees)	Significance	Odd Ratio	Confidence Interval	Nagelkerke R Square
Open and UpRight scanner vs conventional scanner	Total Open Upright Conventional	4916/648747 172/6359 27/6208 4717/636179	<0.01	- 3.72 0.59 -	- 3.19 – 4.34 0.40 – 0.85 -	0.004
Head first entry vs Feet first entry	Total Head first Feet first	4916/647300 2969/276276 1947/371024	<0.001	2.06	1.94 - 2.18	0.011
Head/Neck examinations vs Knee and below examinations	Total Head/Neck Knee and below	2235/295577 2118/202512 117/93065	<0.001	8.40	6.97 - 10.12	0.038
45-64yrs vs all other ages	Total 45-64yrs All other ages	4916/648747 2443/245640 2473/403107	<0.001	1.63	1.54 - 1.72	0.005
Female vs Male	Total Female Male	4811/631442 2889/344508 1922/286934	<0.001	1.25	1.18 - 1.33	0.001
NHS vs Non-NHS funded	Total NHS Non-NHS	4916/648747 4512/574733 404/74014	<0.001	1.44	1.32 - 1.60	0.001

Patient Age

There was little evidence of difference (p=0.97) using an independent t-test in the mean age found between those who were (mean 52yrs (SD 18.1)) and were not claustrophobic (mean 51.6yrs (SD

15.4)). Review of the age groupings (Figure 2) shows the highest incidence of claustrophobia in the 55-64years-old age group (1.03%) closely followed by those 45-54years-old (0.96%). Grouping these ages together (45-64years) and comparing with all others shows statistical significance. Those within this bracket showed an average incidence of 1% compared to 0.6% in all others. As a predictor, logistic regression suggests that those aged 45-64years-old are therefore around 1.5times more likely to fail a scan due to claustrophobia (table 2).

Figure 2: claustrophobia incidence by age group



Additional analysis of the average ages seen between scanner type is summarised in the supplemental data, further suggesting greater incidence in those aged mid-late 50s.

Patient Sex

Incidence of claustrophobia with recorded sex showed 60% of cases were female and 40% male, with respective incidence rates of 0.84% and 0.67%. Binomial logistic regression supported a significant relationship ($p<0.001$ - table 2) suggesting female patients are about 1.25 times more likely to suffer a claustrophobic outcome. Looking specifically at sex and scanner type (table 3) shows slightly more females presenting to both open and UpRight services. For those failing due to claustrophobia, occurrence in both the conventional and open scanners were similar, whereas for UpRight services claustrophobic events occurred over one and half times more in males than females.

Table 3: demographics per scanner type

	Conventional	Open	UpRight	Overall
% pt. sex split of referrals (M:F)	45:55	38:62	41:59	45:55
% pt. sex split of claustrophobic scan failure (M:F)	40:60	43:57	62:37	40:60

Patient Funding

Whether referral was via the NHS or through other funding means, such as medico-legal or private payment, was shown to have a significant relationship on the occurrence of claustrophobia ($p<0.001$ - table 2). Incidence was higher for NHS patients (0.8%) compared to non-NHS (0.5%), with NHS patients being just under 1.5times more likely to be unable to complete an exam.

Discussion

The overall incidence of claustrophobia related incomplete MRI examinations seen during the review period was 0.76%, half that found in the meta-analysis by Munn et al(22). Studies included at that time showed variation in reported figures, with now outdated studies skewing the outcome making it less relevant to current day practice. Therefore, the lower incidence found supports the anticipated downwards trend.

That said, incidence seen matches that of Dewey et al(21) in 2007 who noted a 3-fold reduction from 2.1% to 0.7% following introduction of a short bore magnet design. More recent studies report the occurrence of claustrophobic events to range from 3.3%-9.8%(17,30) but their definition encompasses those needing any support to complete an examination as well as incompletion. Sadigh et al(30) do note an inability to complete an examination in 0.6% of patients but it is not clear whether this is directly related to claustrophobia or other causes.

Therefore, incidence of scan abandon appears relatively stable and perhaps supports the fact that technological advances are still yet to be fully realised to their maximum effect where further reduction is expected. But this metric alone does under-represent the actual prevalence of claustrophobia where patients still experience claustrophobia or anxiety but attend and still manage to cope. The concern of claustrophobia has been shown to be present in around a quarter of patients prior to scanning, which is then not as bad as first thought after the event(6,31). A more severe response may lead to avoidance all together i.e. the patient not attending. Hence, whilst the incidence of scan failure due to claustrophobia is a common metric used to measure service efficiency it is important to acknowledge that this alone does not necessarily explain the full picture in itself or accurately represent high quality care(32). Whether claustrophobia is the true cause of premature termination is commonly a potential misassumption made by imaging staff. Exploring the

experience from patient perspectives helps inform a richer understanding with feedback complimenting data.

COVID-19

The lack of variation in incidence throughout 2019/20 suggests seasonal variation to have little impact, although increased incidence in winter has been previously suggested(33). Whilst data was aggregated for the 2-year review, there was variation noted throughout 2020/21 which is likely related to the impacts of the COVID-19 pandemic (supplemental data).

This increased incidence supports the perceptions of clinical staff(34). The above average increase in occurrence could be related to already heightened anxiety amongst the general population (35,36), with patients attending for scans with increased anxiety around the ongoing pressures of living within restrictions and concerns over attending clinical settings(37). This could in turn affect ability to cope, with attendance for scanning proving too much, as well as not necessarily being able to have someone accompany them to appointments(34). The impact of having to wear a face mask cannot be underestimated for those who may already have some level of claustrophobia, in particular where suffocation is a trigger(38). This in practice has been shown to be challenging for many patients when placed within the scanner. With staff also wearing protective equipment, this potentially presents an additional communication barrier between practitioners and patients, limiting the opportunity to build connection and rapport through simple acts such as smiling or touch(39,40).

Another consideration may have been the variation in workload and patient groups seen throughout the second year (supplemental data). The reduction in relative incidence early on could be attributed to the patients being seen having more clinical urgency for a scan, which could have impacted on increased motivation to cope, compared with those who may attend for more benign conditions and peace of mind. Following this, disruption to services created scan backlogs, and coupled with patients presenting later to referring clinicians, meant that in some cases patient condition, or their concern over it, was negatively impacted. This could have further confounded the experience of general anxiety when attending for scan which may have exhibited as claustrophobia and being unable to complete a scan, providing some account for the increased incidence overall.

Scanner Design

Perhaps unsurprisingly results show an influence over the occurrence of claustrophobia with the physical aspects of scanners themselves playing a key factor on the feelings of confinement and restriction(9,10). What was unexpected was the increased rate seen in the open scanner compared

to the other two. Patient preference is often towards a more open scanner design, particularly by those who have already had a negative scan experience(15,25). This does appear to be supported in the literature with studies looking at non completion rates on open scanners reporting 3.43%(41) and 8.3%(15). Although other studies have also found no significant differences in incidence based on scanner design(17,42).

Whilst open scanners suggest a more panoramic view and wider table, the reality is that the space vertically within the scanner is far less than a modern wide bore system (44cm vs 70cm), and therefore can still feel close once positioned. The patient group seen are predominantly known claustrophobic and have often already failed a prior conventional scan. Therefore, they may attend in a potentially heightened state of anxiety(24) and anticipation around their experience, coupled with often longer scan times(41,42).

Interestingly, the same patient group is commonly referred to UpRight services but the incidence was notably lower. A possible explanation for this difference links back to their design; whilst both are considered open, being sat or stood upright with nothing in front of you naturally puts people at ease compared with lying flat. This supresses the fight or flight instinct and supports control and the feeling of being able to escape if needed with a clear line of view and lack of restriction(43). For this reason, development of UpRight systems is considered a priority by patients, along with more space and less noise(25).

However, it is not just the nature of the scanner itself that is important, but also the receive coils used to detect signal from the area in question. In conventional scanners, coils are closer fitting to improve scan quality and so can enhance the feelings of restriction and suffocation(26). Whereas in both Open and UpRight designs, solenoid coils are used which by their nature are more open and less confining.

Examination Type

Incidence of increased experience of claustrophobia when entering the scanner head first is well supported in the literature (22,33). Previously reported incidence rates for head versus feet first entry have shown a ten-fold increase between the two (2.1% vs 0.2% respectively), with ten times the odds of premature termination(21). Improvements in scanning equipment allow more examinations to be performed feet first potentially improving incompletion rates.

As well as entry, the nature of the examination also has a role to play, with incidence similar to previously reported for head/neck and lower extremity scans (1.73% versus 0.59% respectively)(18). Results show far greater odds of scan failure for head or neck scanning compared to the knee or below. This suggests that differences in the nature of the examinations to be important factors;

namely having a coil placed over the face, as well as head first entry and position within the scanner bore. Although as well as the physical nature of the exam procedure, the clinical consequences associated with a scan are also a consideration, either in terms of increased anxiety or motivation. For instance, a head scan may be more concerning and have greater clinical impact to an individual compared to a knee scan.

Patient Age

Findings in the review support previous studies that have found those aged 45-64years to have a higher incidence (2.6%) of failed scanning due to claustrophobia and calculated odds of failure being 2.1 times(21). Whilst no significant difference was shown in the mean age of those attending and those experiencing premature scan termination, it has been demonstrated that those experiencing a claustrophobic event tend to be slightly older (55yrs vs 52yrs)(18,42). Though the average age of referrals seen across all three scanner types are alike, there is an increase seen in those failing to complete a scan on both open and UpRight services, supporting a potential link with those towards the higher end of the age bracket. Furthermore, a possible link with generalised anxiety disorder, which is common in those over 60years, has been suggested where a termination rate of 6.7% has been reported(44).

Patient Sex

It is well documented that within the general population woman are more prone to experience phobias than men(45). In general terms, women have higher anxiety and concern over their imaging experience(2,6,31,46), with twice the odds of reporting elevated anxiety(1). The greater proportion of women requiring scanning is also representative of other studies(17,21,24,42) and demographics seen at a wider, national level(47).

Therefore, the higher incidence of claustrophobia related termination reported aligns with that of other studies(17,18,21), which have also suggested the likelihood of females experiencing claustrophobia and aborting a scan to be almost twice that of males.

An unexpected observation was the greater incidence in abandonment by males within the UpRight service whilst referral demographics were comparable. One possible explanation for this further relates to design, with men generally having broader shoulders and so feeling constrained from the sides despite nothing being over the anterior of their body.

An interesting point to note connecting both age and sex, is that together there is an increased likelihood of someone terminating a scan if female and in their 50s. These two attributes together therefore raise an important consideration around how menopausal status and related

anxiety(48,49) may impact on scan completion. Indeed, in a study on breast MRI(50) with a similar age distribution, a much higher than normal 25% refused scanning due to feelings of claustrophobia, with 0.4% unable to complete an examination.

Patient Funding

An increase in incidence of claustrophobia within NHS funded patients supports previous findings where incidence was higher in state funded versus privately insured patients (1.8% vs 1.5%)(21), raising interesting areas for debate around the potential impact of financial consequence on motivation to overcome fear.

Drawing on the biopsychosocial model of challenge and threat in the context of fear, an appropriate motivator can be enough to supports one's behaviour to tackle and overcome concerns(51). In this context, the potential financial consequence of failing a scan may be enough to motivate, or maybe those persons privately funding are more inclined to take ownership of their health. Conversely it may be argued that those with higher income to afford insurance may be less concerned over potentially wasted payments(52). Whereas for scans that are government funded, there is no obvious cost or financial consequence to failure, which could in itself inhibit self-motivation to necessarily tolerate a scan.

Wider influences such as socioeconomic status and deprivation are complex and known to have an impact on health inequalities and access, with high levels of deprivation associated with increasing levels of physical and mental discomfort related to MRI(53). Of course, the overriding motivation for most is to achieve a scan for diagnosis and answer a clinical question, the consequences being not knowing or delay to treatment.

The Bigger Picture

The numbers of patients unable to complete a scan due to anxiety or claustrophobia may be low, but even one patient failing to succeed in having an MRI scan impacts on their diagnostic journey and onward management. This itself can incur additional costs in delayed diagnosis or mismanagement. As a proportion of those examinations that go incomplete, claustrophobia accounted for 30% which is a significant proportion worth addressing. Therefore, there remains a strong financial basis to drive ongoing improvements to further improve patient experience and reduce the incidence of scan failure.

Whilst review of the readily available patient characteristics provides an idea on which groups may be more likely to suffer an anxious response or what the specific triggers may be, what is not

captured are other comorbidities or factors that may deepen the picture. For instance, previous cardiac surgery with history of diabetes and hypertension has been shown to increase a fear response to MRI and at a younger age(54). Those with a diagnosis of multiple sclerosis were more fearful of results and disease progression rather than the scan itself, although that said, previous evidence suggests anxiety of the scan itself did not improve having had more scans(3). Patients with different requirements, such as varying levels of autism, require adjustments to support their experience(55,56).

These additional factors show how complex and dependent on the individual scan related anxiety may be, and how challenging prediction of potential claustrophobic reactions are. Use of questionnaires, such as the claustrophobic questionnaire or anxiety sensitivity index, have shown promise as useful predictor tools(17,44,57). Being able to identify those at risk could allow additional time or resources to be provided in advance to support patients and scan success, particularly where time is considered a barrier to be able to sufficiently do so in clinical practice(34). Perhaps moving forwards, this is where the use of artificial intelligence could have a role, drawing on individual data and using algorithms to enhance patient centred services through providing individualised scheduling and tailored information.

Some final points to raise that are not readily demonstrable on data go beyond simply considering scanning equipment, examination type and patients alone. The supplemental data includes a sample of cross site data from different service models. This demonstrates the wider variation in incidence rates seen across different sites, suggesting that additional factors may be at play, not solely the confines of the equipment design itself(4). The influence of wider environmental impact is a consideration, such as the sterile appearance of many departments and the additional space restrictions on mobile units. The operational culture is another aspect, where private sites may be given more time with less pressure to rush patient through at the detriment of patient experience. Conversely NHS services within the community and mobile setting likely suffer as a result of importance placed on throughput over experience. In fact having sufficient time to support patients is noted by radiographers as a barrier(34).

Although perhaps the biggest factor that cannot be accounted for is the importance of staff interaction and the impact this has on scan success. Interestingly studies looking at the effects of team training(19,41) on completion rates have shown significant reductions, ranging across different scanner sites between 0.3%-3% failure. Therefore, staff training and experience in effectively managing and caring for patients is perhaps the biggest influencer and source of variation in practice that cannot be readily evidenced.

Limitations

There are some limitations to consider when reviewing the analysis of the data reviewed. The volume of data reviewed means site variation is lost but does help provide a benchmark against which sites can measure themselves overall. As with any data, it is only as accurate as that inputted initially, and so some variation was present between sites and contracts. A generalised assumption was also made with certain exam codes as to how patients may have been placed within the scanner.

Only those services using a specific radiology information system were captured which meant that the focus was predominantly on static locations, thereby limiting the breadth of the review. Deeper comparison between locations and with mobile services would be useful to compare occurrence and inform improvement. Likewise, only the presented patient information was available through the system and other factors, such as patient body habitus, may have been beneficial. Other aspects beyond the scope of this review but that may also have been beneficial to capture and consider would be; further background on staffing levels and experience of those providing the service, as well as how previous experience of scans may impact reattendance and compliance by patients.

Conclusion:

This review benefits from a cross national, multi centre view from within the UK drawing on a large data set. Results suggest that the incidence rate of incomplete scans due to claustrophobia may have dropped below 1% as previously predicted(22). This has the potential to fall further with the continued development and utilisation of improved scanner design and technology.

However, there are important contributory factors for clinical staff to consider when managing patients attending for MRI. In particular, likelihood of claustrophobia increases with females, those between 45-64years of age, funded by the NHS and entering the scanner head first, and/or having a head scan. Use of UpRight scanners appear to be better tolerated as an alternative to conventional scanners, and with the increasing development of machine learning algorithms that enhance signal and resolution, this could support increasing development of more open, lower field systems without compromise to diagnostic quality. Although it is important to consider the impact of wider influences that cannot be shown through operational data and failure to scan alone.

In the context of increased patient numbers and an ever increasing need to manage resources post pandemic, the cost of incomplete scans from claustrophobia is still significant and an area worth ongoing investigation and improvement. There is value in further exploration around any means that can help improve patient experience and reduce scan failure due to anxiety or claustrophobia.

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