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Challenges associated with x-ray imaging of stretcher-bound patients

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A review of the clinical and technical challenges associated with x-ray imaging patients on hospital stretchers

After completing this Directed Reading, readers should be able to:

Understand the main differences that exist between imaging on an x-ray tabletop and stretcher with particular reference to acquisition parameters.

- *Explain possible complications associated with imaging on a stretcher and how to overcome them.*
- *Understand the advantages and disadvantages of imaging on a stretcher which will allow for a more informed decision as to whether to transfer the patient onto the x-ray tabletop in certain situations.*
- *Evaluate stretcher design in order to make an informed decision as to its suitability for imaging.*

Introduction

Hospital stretchers are essential for imaging unstable or severely ill patients. Stretchers help to significantly reduce moving and handling risks for patients and staff. Patients are imaged on stretchers because transferring them onto an x-ray tabletop could cause further harm, exacerbate pain and result in further discomfort. This is especially the case for patients who may have multiple injuries.[1] In these circumstances radiographers are routinely faced with the challenge of producing images of diagnostic quality while the patient remains on the stretcher. In these situations a variety of physical and technical parameters should be considered, including image receptor (IR) holder, mattress construction and thickness, object to image receptor distance (OID), source to image distance (SID), the use of a stationary radiation grid and the lack of availability of automatic exposure control (AEC). These variables may influence the selection of the acquisition parameters for stretcher imaging since they distinctly differ from those used when imaging on the x-ray tabletop. To date, we have not found any published optimisation studies exploring the selection of acquisition parameters when imaging patients on a stretcher or that evaluates their relationship with image quality and radiation dose for such a situation.

This article aims to review the challenges of x-ray imaging patients on a stretcher. Stretcher design will firstly be evaluated followed by the technical variations between stretcher imaging and x-ray tabletop and lastly previous published studies specifically conducted on stretcher imaging will be evaluated.

Stretcher design

Considerable differences exist between dedicated x-ray table tops and stretchers. Some stretchers have design features with x-ray imaging in mind; others do not. Ideally a stretcher should combine the needs of multiple patients across a range of clinical scenarios which may or may not include x-ray imaging. Stretchers are sometimes referred to as trolley or gurney.

Stryker Medical is one manufacturer who offers flexible stretchers with x-ray imaging in mind. Stryker(R) recently introduced their multipurpose Prime X stretcher into practice.[2] This stretcher allows patients to remain on *one* stretcher for transportation, treatment and x-ray imaging; in turn this reduces time, cost and the risk to both patient and staff from injury occurring when transferring patients to and from a stretcher. Literature indicates the importance of minimizing patient movement when there is concern about injures.[1,3,4] According to the United Kingdom's Royal College of Radiologists, moving a severely injured patient can cause delays and exacerbate blood loss. [5] The less a patient is moved and the shorter the distance of movement, the greater the chance of survival. It is also important to consider staff safety during manual transferring of patients from stretcher to x-ray tabletop and vice versa. Work-related injuries are an important consideration for healthcare practitioners with injuries occurring often during transferring, repositioning, lifting or moving patients.[2] In certain situations it can, therefore, be appreciated that if it is possible to acquire images of diagnostic quality on the stretcher, it would benefit both the patient and staff by minimizing unnecessary transfers.

There are essential design features that a stretcher must possess to ensure its suitability for x-ray imaging purposes. Many of these features, indicated in Table 1, are highlighted in manufacturer brochures and textbooks.[2,6-8] As seen in Table 1, imaging stretchers require a number of *essential* features; however, different manufacturers offer *additional* features in order to improve their design and ultimately utility. The additional features are not compulsory for successful stretcher imaging and often incur an extra cost. Table 2 demonstrates a range of different design features for five commercially available stretchers suitable for x-ray imaging. Essential design features comprise the minimum specifications required to enable the radiographer to image the patient safely and successfully on the stretcher. The imaging departments should therefore be involved in decision making and evaluating new stretchers during procurement to ensure they are fit for purpose; this becomes paramount when the lead department who intends to purchase the stretcher is not the imaging department (e.g. emergency department).[8] A number of essential stretcher design features are now considered:

The image receptor (IR) holder

Many imaging examinations of stretcher-bound patients cannot be acquired with the IR directly in contact with the patient due to the potential of exacerbating or inducing injuries. Such examinations include AP pelvis, AP spine(s) and AP supine chest projections. Consequently, the stretcher requires an IR holder (either a tray or platform) similar to an x-ray tabletop Bucky, to accommodate the IR and in some cases a stationary grid. The IR holder is commonly referred to as a stretcher cassette holder.[8] The design of the IR holder varies from one manufacturer to another with some designs restricting the angulation or rotation of the IR.

There are two different types of IR holders, one is designed similar to a Bucky mechanism as found under the x-ray tabletop and is referred to as a **tray** while the other type is referred to as a **platform** (or opening under stretcher). The stretcher tray is a device where the IR is placed in a drawer and slid into place prior to an exposure (Figure 1). The platform on the other hand is an opening under the stretcher which is parallel to the stretcher tabletop in order to accommodate the IR (Figures 2 and 3 show examples of two different platform designs). In comparison to the tray, the platform offers more flexibility especially when patients are not central to the stretcher or when the IR needs to be angled for patients that are not lying straight on the stretcher. The stretcher tray can therefore cause practical problems to radiographers since patients are rarely perfectly centralised on the stretcher and often lie obliquely across its central axis.[9] If the stretcher has a tray and the patient is not centralized it may require the patient to be moved to coincide with the axis of the tray; this can be a common reason for generating repeats due to anatomy cut-off.

It is important that the radiographer is able to visualize the position of the IR between the stretcher top and platform to ensure accurate alignment relative to the patient before making an exposure. Unfortunately this is not an entirely accurate method of assessing alignment, and this problem has been identified by Mutch and Wentworth, where radiographers within their study commented on the difficultly of aligning the IR and patient when using a tray mechanism in the incubator.[10] This situation is exacerbated when the tray or platform are used to store patient belongings e.g. clothing thus further impairing visibility. On the x-ray tabletop there are physical and electronic indicators when the IR within the Bucky is aligned to the x-ray tube and therefore the issue of having to visually predict alignment is not a problem. There are some visual indicators on the stretcher as seen in Figures 2 and 3 to help align the IR but again these just help with predicting alignment. This issue of alignment on stretchers may potentially result in cutting off relevant anatomy.

Stretcher surface and mattress

Ideally, the entire length and width of the stretcher surface and mattress have to be uniformly radiolucent. According to Whitley et al. metal bars and hinges on the edges of the stretcher surface may cause image artifacts when using the tray or platform which would be exacerbated when angulation of the tube is required.[8]

The stretcher mattress is another important factor to consider. In comparison to the mattresses used on x-ray tabletops, stretcher mattresses tend to be thicker and constructed of different materials to meet standards associated with tissue viability, infection control and durability, since patients can remain on a stretcher for long periods of time.[11] In Canada, there have been concerns of patients lay on stretchers in the emergency department for long periods of time awaiting hospital beds.[12] This problem has also been noted in the UK which raises concerns over pressure ulcers.[13,14] Pressure ulcers are injuries that often develop in patients who remain in one position for prolonged periods. The elderly are particularly at risk in addition to those with injuries that limit mobility (e.g. suspected neck of femur fracture) are at even higher risk. [15] Due to this complication, patients are usually placed onto thicker [pressure redistributing] mattress on admission and consequently imaged on these mattresses.[16]

As seen in Table 2, mattress thickness varies between manufacturers. Manufacturers tend not to specify the density and construction of their mattresses however this may be available upon request. Most stretchers come with a standard mattress with most manufacturers, including Stryker, ArjoHuntleighs', and Seers offering a replacement thicker mattress to enhance patient comfort and to reduce the possibility of pressure ulcer development. For example ArjoHuntleighs standard mattress is 65mm in thickness and made of plain foam pads whereas their replacement Bi-Flex mattress (130mm) is constructed of pressure distributing foam (see Figures 4 and 5). Disappointingly, few studies are available which investigated the impact that these mattresses have on radiographic technique, image quality and radiation dose.

An example where imaging has been considered before introducing a newly proposed mattress comes from the United Kingdom's National Institute for Health and Care Excellence (NICE).[17] NICE provided some information on the potential impact of this new warming mattress on radiation dose and image quality by comparing it to two other imaging mattresses which they termed as '*low-attenuating x-ray mattress*' and '*x-ray stretcher mattress'*. Comparisons were established by calculating the aluminium (Al) equivalent of the mattresses in order to determine their radiation transmission capabilities. NICE estimated that the low attenuating x-ray mattress was 0.2mm Al equivalent whereas the x-ray stretcher mattress was 1.0mm Al equivalent. Surprisingly, NICE did not specify the make, type, or thickness of the mattresses used in their comparisons. It is therefore difficult to generalise and put this information into context since there are several commercially available mattresses for x-ray tabletops and stretchers on the market. In addition, manufacturers do not ordinarily specify the Al equivalent of their mattresses therefore it is also difficult to compare these estimations from the NICE guidelines to the mattresses described in Table 2. NICE comment that the mattress in question did not affect x-ray image quality or radiation dose however this was based on observations made by users confirming that clinical practice had not changed when using this new mattress. NICE conducted a small experiment to determine the effect of the new warming mattress on image quality, however there were no details on how image quality was assessed. The lack of scientific evidence for the assumptions made by NICE regarding the effect of the mattresses under question makes it difficult to interpret and transfer to clinical practice. This example above highlights that products can easily be deemed acceptable from an imaging perspective without rigorous empirical evidence to support it.

Another point to consider is that some radiology departments do not use mattresses on their x-ray tabletops and such is the case in many departments.[18] When manufacturers such as Siemens Healthcare and Philips Healthcare launch new x-ray rooms, the advertising images do not demonstrate a mattress. This is because radiographic mattresses are sold separately. This could mean that anatomically programmed radiography (APR) systems and exposure charts used in imaging departments are based on imaging techniques performed without the use of mattresses. Radiological surfaces are designed by manufacturers to be radiolucent and any mattress added to this would likely incur an increased patient radiation dose.[19] From an image quality and radiation dose perspective, acquiring images without a mattress is better. However a study by Everton et al. highlights the potential for the development of discomfort and pressure ulcers if patients remain on the tabletop for long periods of time without a mattress.[20] Everton et al. also demonstrated a significant difference in pain and comfort levels between the two imaging surfaces (a surface with and without a mattress) and therefore not using a mattress on tabletops may result in more patient movement caused by discomfort during imaging.

Unavailability of the AEC

For many radiography examinations the AEC is utilized as an x-ray exposure termination device.[21] AEC is considered to be a dose reducing and image quality standardising device since the exposure terminates when the IR has received a threshold exposure level. It takes into account the thickness and density of the body part being imaged and this should reduce operator subjectivity / variability. [22] The use of the AEC is recommended by the American Society if Radiologic Technologists and the International Commission on Radiological Protection (ICRP) when imaging specific body parts such as the abdomen, pelvis and spine.[23,24] When imaging a patient on a stretcher, the AEC is not available and this situation requires the radiographer to set their own exposure factors. This can result in higher radiation doses than necessary and also the potential for dose creep to occur.[25] There have however been recent discussions exploring the idea of integrating an exposure control sensor (similar to the principles of the AEC) with signal detection into digital radiography in order to increase its flexibility and use. Some manufacturers have already started introducing this new technology.[26]

Geometric factors

The geometric factors that need consideration for stretcher imaging are predominantly SID and OID. SID was previously referred to as film to focus distance (FFD), or also more recently referred to as focus to receptor distance (FRD). It is the linear distance from the focal spot of the x-ray tube to the IR. According to the inverse square law it affects contrast and if doubled, the intensity of the x-ray beam will be reduced by one-fourth.[27] SID also affects magnification and distortion on the resultant image i.e. magnification will reduce if SID is increased. In clinical practice each projection has a suggested standard SID in order to reduce variability and provide consistency in image quality.[28,29] OID is the distance from the object being exposed to the IR. It is another factor that influences magnification and geometric unsharpness. The closer the object being imaged is to the IR (reduced OID), the less the magnification, and the better the detail and image resolution.[30,31] Carroll & Bowman recognised that there will always be a trade off when imaging on a stretcher where radiographers are often forced to choose which factors to sacrifice: a slight increase in unsharpness and magnification, a slight loss of contrast, some distortion of anatomy or the clipping of anatomy if SID is not appropriately increased.[32]

When the IR is placed in the stretcher IR holder, whether it is in the tray or on the platform, this will increase the OID (Figure 6). OID magnitude will depend on stretcher design and mattress thickness. Some manufacturers (e.g. Lifeguard 50, ArjoHutleighs; Figure 3) offer an elevating platform in order to reduce the OID to bring the IR closer to the patient. A stretcher tray on the other hand does not require elevation (Figure 1); there are also some stretcher platform designs, as seen by Stryker Prime that do not require elevation (Figure 2).[2] As already discussed, stretchers also tend to have thicker mattresses, consequently OID is increased further. Carver and Carver support this notion and comment that OID is greater on a stretcher in comparison to the table Bucky setup.[9] By placing the IR in the holder beneath the stretcher and with the patient positioned on a thicker mattress this can considerably increase OID which increases magnification and geometric unsharpness. This is why it is an important feature on a stretcher that its height can be lowered in order to maintain the required SID and offset this magnification. This is especially important when undertaking a supine chest due to magnification of the heart.[33] This problem was identified in a study which explored the effect of increased OID owing to stretcher design on the magnification of the mediastinum during AP supine chest imaging.[34] Within the study, the thickness of stretcher mattresses and the IR holder was identified as problematic and OID varied between six commercially available stretchers. Although the stretcher can be lowered and SID increased to compensate for the increased OID, this is limited by the radiographer’s height and restrictions within the x-ray room. The effect of increased OID for stretcher imaging needs explored further because increased OID not only increases magnification but it also results in geometric unsharpness which will reduce image detail.[8]

An increase SID is required for an increase in OID not only to compensate for magnification but to ensure all require anatomy falls within the edges of the IR. Carroll and Bowman, recommends an increase in SID in this situation also to take advantage of beam divergence and hence bring in the collimation.[32] Increasing SID has previously been shown to reduce radiation dose to patient without impacting on image quality, however there is still controversy as to how to modify acquisition parameters for this situation. Carroll and Bowman suggested that for every 25cm increase in SID, mAs needs to be adjusted by at least one third (35%). In addition, if adhering to the mathematics of the inverse square law, when 16mAs is used at a distance of 100cm as is subsequently increased by 25cm, it would require an increase of 9mAs (16mAs to 25mAs) which is more than one third. Yet again recent literature specifically exploring this increase in SID to reduce patient dose concluded that there was no visual impact on image quality when SID was increased for AP pelvis with the mAs kept consistent.[35-37]

Another consideration for stretcher imaging is the requirement for manual measurement of SID. When imaging on an x-ray table top using the Bucky, there are light indicators on the tube housing to confirm if the x-ray source and IR are aligned to the midsagittal plane and that the correct SID has been achieved. These are governed by sensors which illuminate and automatically notify the radiographer when there is correct alignment (source and IR) in all planes (long axis, short axis and distance) (Figure 7). These indicators are important to minimize the chance of excluding important anatomy, to avoid grid cut-off and also to ensure practice consistency.[38] However, for stretcher imaging the SID has to be measured manually using a measuring tape incorporated into the light beam diaphragm (LBD). This requires the radiographer to measure SID at the side of the stretcher and then re-position the x-ray tube over the patient (Figure 8). This has the potential to cause major inconsistency and accuracy issues with SID.[4]

Grid selection

A secondary radiation grid can be used to reduce scattered radiation reaching the IR in order to improve image quality; they can be oscillating or stationary. An oscillating gird is incorporated into the x-ray tabletop Bucky and moves during an exposure in order to minimize the shadows of the gridlines on the resultant image. It is the most desirable type of grid as it helps minimize grid artifacts.[30] Nevertheless, this type of grid is unavailable for stretcher imaging and a stationary grid has to be used instead. A stationary grid does not move during an exposure and needs to be fitted to the IR prior to exposure. In comparison to an oscillating grid, the opaque strips found in a stationary grid are thin and close together such that the grid can remain stationary without the shadows of the strips being sufficiently visible to interfere with image detail (e.g. Lysholm grid). Different acquisition parameters may be needed, depending on the grid type.[8] This suggests that exposure factors used for the oscillating gird on the x-ray tabletop may not be directly transferable to a stretcher patient with a stationary grid.

Currently used grids are often focused with the lead strips are aligned in a slanted fashion towards a centering point. These grids have a minimum and maximum SID tolerance in order to avoid grid cut off.[8] The radiographer must therefore be accurate when measuring SID to avoid cut off artifact from misalignment causing visualisation of lead strips shadows on the resultant image.[27] The focus tolerance of the grid becomes problematic for certain examinations during stretcher imaging for two reasons. Firstly, an increased SID may be required for stretcher imaging to compensate for the magnification caused by the mattress and position of the IR holder. The radiographer in this situation has to consider how much they can increase SID before gird cut off becomes apparent. Secondly, accurate measurement of SID can be difficult for stretcher imaging in comparison to x-ray tabletop imaging since it requires manual measurements of SID using a measuring tape. Recent literature on increasing SID to reduce patient dose have not visually experienced any image quality deterioration at increased SID over the recommended tolerance range of the grid.[35,39,40] However these studies have been conducted using oscillating grids on x-ray tabletops and therefore cautions needs to be taken before applying it to stationary girds. Further work would be beneficial to evaluate using an increased SID for stationary grids.

Previous published studies related to stretcher imaging

A comprehensive literature search was conducted to search for specific peer-reviewed articles on stretcher imaging. The search was performed using a systematic approach using several databases including Science Direct and Cochrane with several peer reviewed journals also individually searched including *Radiologic Technology*, *Radiation Protection Dosimetry*, *European Journal of Radiology*, *Radiology*, *American Journal of Roentgenology*, *British*

Journal of Radiology, Radiography, Journal of Medical Imaging and Radiation Sciences, and *Medical Physics*. While undertaking a scope of the literature, relevant key words where used including *digital radiography, trolley, stretcher, optimisation, image quality* and *radiation dose.* Due to the limited literature found initially on stretcher imaging, no time restriction with regards to publication date was placed on the search in order to maximize the likelihood of finding relevant articles.

This comprehensive literature review revealed limited published work relating to imaging patients on stretchers, especially studies investigating the effects of the stretcher design on image quality and radiation dose. From this search strategy, only four studies were found that met the search criteria, with all of them being 10+ years old. The following section takes into consideration these prior studies however their publication date clearly reflects that stretcher imaging has not received much attention.

The first relevant study was a questionnaire-based study whereby radiographers across three district general hospitals in the United Kingdom were asked about their current working practices in association with stretcher imaging. The aim of this study was to explore whether there was variation in practise when imaging stretcher patients.[41] It was discovered that acquisition parameters used for stretcher patients were based on APR values which are pre-programmed exposure techniques set on the control panel for average patients imaged on the x-ray tabletop but also on the radiographer's professional judgement. This study had a response rate of 65% which accounted for two thirds of the radiographers working within these hospitals. The results of this study demonstrated a considerable variation between radiographer's practice and their understanding of different variables when imaging a patient on a stretcher. One of the most important findings from this study was that more than 50% of radiographers increased their exposure factors from the recommended values on the APR system for stretcher imaging without any clear evidence to support this. The study demonstrated that 52% of radiographers either strongly agreed (n=3) or agreed (n=31) that an increase in mAs is necessary for imaging patients on a stretcher using the tray/platform beneath it while 26% (n=17) were undecided. This is especially worrying considering that after the introduction of digital systems in radiography a phenomenon called 'dose creep' became apparent and recognised by several authors.[25,42] The radiographer can increase dose quite a lot without degrading image quality; Ma et al went on to suggest that 'dose creep' can occur frequently in examinations where the AEC is not available and some radiographers may increase their mAs to ensure the image is acceptable on the first attempt.[25] This concept is worrying as the AEC is unavailable for stretcher imaging and there are no set protocols specifically related to this imaging technique.

Careful consideration must, however, be given to the results of this study as it cannot be assumed that the same variability and opinions exists in other x-ray departments. Also, this article was published in a radiography non peer reviewed magazine although it was still reviewed by an individual within the profession and can therefore still be deemed valid to reflect the current working practice in one area within the United Kingdom.

The second relevant study on stretcher imaging was conducted by Gleeson et al. in which supine chest imaging on stretchers and the impact of components such as the mattress and IR holder on magnification of the mediastinum was examined.[34] Gleeson et al. identified problems when imaging patients on stretchers and explored the effect stretcher imaging had on magnification in supine chest imaging. The problems identified by Gleeson et al. included the introduction of advanced trauma life support (ATLS) which sees patients being pre-packaged on spinal boards and placed on a stretcher with a thick mattress consequently inhibiting the placement of the IR directly behind the patient for imaging. The introduction of the spinal board, the thick mattress and the IR holder beneath the stretcher has therefore increased the distance between the IR and the area being imaged. Gleeson et al. wanted to explore this increased OID which has exacerbated magnification in order to determine its effect on the diagnosis of thoracic trauma when chest imaging. When calculating magnification, Gleeson et al. compared the affect of six commercially available stretchers on mediastinal diameter however the name of the stretcher manufacturers were anonymous. The six stretchers caused different distances between the spinal board and the IR holder, ranging from 7.1 to 12.9 cm. This suggests a large manufacturer variation in stretcher design resulting in incomparable magnification level when imaging on different stretchers at identical SIDs. '*Radiographic techniques have to be adapted when imaging stretcher bound patients*' was one of the concluding statement made within this study; however, no recommendations were made regarding specific modification requirements for technique or acquisition parameters. In addition, this study by Gleeson et al. was carried out more than 10 years ago yet no follow up research study was found addressing the issues raised by this study. The impact of stretcher design on chest magnification was the only outcome measure evaluated for this study and therefore stretcher design and mattress plus geometric factors were not explored in terms of their effect on radiation dose and image quality.

One of the other studies found explored how different spinal boards affected image quality, radiation dose and the attenuation/transmission of radiation.[43] Although this article did not relate specifically to stretcher imaging, it does highlight some of the challenges of trauma imaging. It can also be assumed that patient who presents to the imaging departments on spinal board are on stretchers and therefore may remain on them for imaging. From an imaging perspective these boards need special consideration since they are an additional object placed in-between the patient and the IR and are therefore in the path of the x-ray beam. Linsenmaier and colleagues found that radiation transmission was similar for all boards but with dose areas product (DAP) differed by up to 59 %. This study did not however compare the difference in radiation transmission and DAP between the spinal boards and the absence of a spinal board. Five different spinal boards were compared to each other which helped to indicate the optimum spinal board to utilise for imaging rather than the impact different spinal boards have on image quality and radiation dose compared to imaging without the boards. Linsenmaier et al. demonstrated that the spinal boards' increased DAP and also had an impact on image quality due to image artifacts. Similar to Gleeson et al. the study did not consider whether and how acquisition parameters should be modified when imaging with the patient lay on a spinal board.[34]

One limitation when evaluating this article was that only the abstract was available in the English language as opposed to the full text that was originally written in German. Careful interpretation of the information provided is therefore required since the in-depth detailed description and analysis of the method and results are missing and there may also be inconsistencies between what has been reported in the abstract and what has been stated in the full paper.[44] Also this study was conducted in Germany in 2001 where the use of spinal boards was still considered gold standard. Nevertheless, recent research has been conducted which questions the use of spinal boards. Log rolling the patient on to a spinal board should be avoided according to Conrad et al. as it can exacerbate injuries.[45] Theodore et al. demonstrated that patients had better neurological outcomes when spinal immobilization was not used.[46] Further studies have also demonstrated limitations to immobilization protocols such as delays in resuscitation, increased anxiety and pressure ulcer development.[47-51] Although the study by Linsenmaier et al. is outdated and does not specifically explore stretcher imaging, it does demonstrate that spinal boards (an object that lies in-between the patient and the IR) increases the radiation dose to the patients and can produce artifacts on the resultant images.[43]

Mutch and Wentworth explored a similar imaging situation to stretcher imaging.[10] The main aim of the study was to evaluate the effect of placing the IR in a dedicated slot within the incubator in comparison to the standard method of imaging which in Mutch and Wentworth's case was a direct exposure (IR placed directly behind the neonate).

Premature newborns are placed in incubators in order to maintain suitable environmental conditions. Neonates often require imaging where the radiographer acquires the images with the neonate remaining in the incubator. Similar to stretchers, there are a variety of different incubators available, each having their own design. Some incubators have a dedicated IR holder beneath them in order to reduce the risks associated with placing the IR directly behind the neonate. The difference between these two scenarios was investigated by Mutch and Wentworth.[10] They found that in comparison to placing the IR directly behind the neonate, the mattress and IR holder mechanism caused a 49% reduction in IR dose although this did not equate in a 49% increase in neonate dose. When allowing for the inverse square law, the difference in distances (OID) between a direct exposure and the IR placed in the IR holder would account for one-fifth of the reduction in IR dose. This means that the remaining reduction must have resulted from attenuation by the materials between these two imaging conditions. In addition, this large reduction in IR dose did not result in deterioration in image quality; there was minimal effect.

The results of Mutch and Wentworth's study are interesting and they demonstrate the potential impact of absorbing materials in the path of the x-ray beam on IR dose; however, these results should be carefully interpreted due to several methodological limitations.The radiation dose quantity used in their study was IR dose. This quantity is not a universally accepted dose quantity and has limited use in optimization studies. It is also not cited in radiation protection reports such as those from ICRP.[52] From a radiation protection perspective, IR dose does not consider the risk to the patient and it is also not fully understandable in terms of its correlation with image quality.[53]

Although significant IR dose reduction was found between the two scenarios presented within their study, there was no impact on image quality. Nevertheless, the method they used to evaluate image quality may have been limited. They used a Leeds Test Object which is a test phantom designed for routine quality control to quantify the degree of threshold contrast in each image using one of themselves as authors to observer and assess this. Not only could this introduce bias into the study but it can also introduce subjectivity due to the relaxed and unstructured nature of the visual evaluation. It would have been beneficial to use more than one independent observer to assess the images using stricter image criteria with repeated measurements taken at time intervals in order to ascertain intra and inter-observer variation. The importance of using multiple observers when evaluating image quality is highlighted by many studies. [54-56] In addition, a Leeds Test Object does not resemble patient clinical imaging and therefore this method may not always be suitable for evaluating different imaging systems or imaging techniques, since their contrast could behave differently to the contrast of clinically relevant details with a changing radiation quality. [57]

These four studies were found when specifically searching for studies focusing on stretcher imaging. Nevertheless, only the first two articles were directly related to the challenges associated with imaging on a stretcher whereas the latter two articles were only in-directly related and helps reinforce the challenges. They all highlight and emphasized the importance of studying imaging conditions and techniques that vary from standard imaging techniques in order to understand their effects on image quality and radiation dose. This is important because the APR system and exposure charts found in imaging departments are programmed for standard clinical examinations and do not take into consideration these modifications in clinical practice e.g. increased OID and objects placed in the path of the primary beam. Although, the APR system and exposure charts should only be used as a guide to help the radiographer's clinical judgment as to the appropriate exposure factors required for each examination.[58] It is the radiographer's responsibility to modify these parameters when necessary; however, this can be challenging if there is no empirical evidence to suggest or support how and when modification is necessary. This limited empirical evidence can result in a wide variation in exposure factors across a variety of examinations since clinical judgment is highly subjective but may contribute to the dose creep phenomenon.

Summary

When patients present on a stretcher to the imaging department, transferring the patient onto the x-ray tabletop is a difficult decision. Transferring patients can cause them further harm however it is standard practice to image patients on the dedicated x-ray table. If the patient remains on the stretcher for imaging, many factors need to be considered before acquisition can take place. These factors have been discussed in detail in this article and they include grid usage, stretcher and mattress design, IR holder, exposure factors owing to the unavailability of the AEC and geometric factors (SID/OID). Optimisation of image quality and radiation dose for stretcher imaging is of paramount importance because there are currently no specific guidelines for radiographers when having to adapt technique for imaging stretcher patients. This review highlights upon the limited evidence available for stretcher imaging hence why some old seminal references have occasionally been used. This is clearly a fundamental issue which needs further understanding and recognition.

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