Advanced Imaging Equipment: Fluoroscopy

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Introduction

The fundamentals of medicine are based upon the diagnosis and treatment of disease. There have been constant developments in medical science since its origin. The introduction of more cutting edge technology has enabled enhanced diagnostic capabilities, consequently bringing more precise diagnosis. This constant evolution of technology has also enabled the radical development of traditional imaging modalities, as well as bringing about new treatment modalities. "Conventional film radiography is restricted to static patient investigations. If dynamic events need to be studied, i.e. movement of contrast material through blood vessels or the gut, the image must be viewed directly using fluoroscopic methods." (Dowsett & Kenny, 2006, p. 253) This paper will investigate the imaging modalities of Fluoroscopy, investigating the equipments for fitness for purpose and whether it meets the requirements of set guidelines.

Main Purpose

Before the introduction of x-rays the necessity of being able to look into the inside of the human body was not realised. X-ray technology has been enhanced by the development of fluoroscopy which has gone a long way in improving the inadequacies of general x-rays. Fluoroscopy can be defined as; "an imaging modality that provides a continuous image of the motion of internal structures while the x-ray tube is energised. Real time imaging."

(Bushong, 2004, p. 609) . Fluoroscopy can be used solely to aid a diagnosis or used in combination with other diagnosis tools. Prior preparation of the patient may be required before certain examination (this could be carried out in the form of a barium swallow). The imaging modality of Fluoroscopy enables the health professional to investigate several different systems of the body, for example the; skeletal system; digestive system; respiratory system; and reproductive system. Specific areas can be isolated for examination such as bones; muscles; joints and organs i.e. the heart. This additional capability offered to the health care professional has led to fluoroscopy being used for several examinations and procedures including; cardiac catheterization, improved adequacies in imaging of joints; placements of catheters; intravenous pyelograms; hysterosalpingography; and also biopsies. Cardiac catheterization and intravenous catheter placement are procedures in which fluoroscopy is used as an adjuvant to aid in the safe and correct implementation of the procedure. In cardiac catheterization fluoroscopy the health profession can easily observe whether there are any blockages in the coronary arteries. 'Barium x-rays' shows fluoroscopy being employed alone to aid in the examination of the digestive system. It demonstrates well the movement of the intestines as the barium passes through.

Description of Equipment and Fitness for Purpose

Early fluoroscopy equipment was performed using phosphor screen technology, however this lead to a high operator dose. Electronic intensification is now used which has also has an improved sensitivity (Dowsett & Kenny, 2006, p. 253). Image production in Fluoroscopy is generally now maintained by use of an image intensification tube. "X-rays that exit the patient and are incident on the image intensification tube are transmitted through the glass envelope and interact with the input phosphor, which is cesium iodine. When an x-ray interacts with the input phosphor, its energy is converted into visible light. (Bushong, 2004, p. 360) This method of image production requires a lower radiation dose for the production of one image compared to general radiography. However the detail is not as fine, making diagnostic quality poor. For the procedures that involve fluoroscopy, the image quality is adequate it maintains that patient and operator dose can be kept as low as possible, as several exposures can be taken in an examination. Ionising Radiation (Medical Exposure) Regulations 2000, state that only image intensification or a similar technique can be used for fluoroscopy, the use of such devices ensure compliance with the legislation.

Display of the fluoroscopy image can be obtained by use of; a vidicon camera; plumbicon; or a charge coupled device(CCD). The techniques convert the light image from the image intensification tube into an electrical signal which is then sent to a television monitor. "Both soft copy(video) and hard copy(film) are available as output displays for the image intensifier" (Dowsett & Kenny, 2006, p. 263). Imaging systems such as dental do not have a requirement for fast image capture, i.e. in the demonstration of teeth the anatomy imaged is stationary. However, fluoroscopy (particularly in the cardiovascular department) has a requirement for a fast image capture, in these cases the vidicon camera is not sufficient as it suffers from image lag. The plumbicon camera has a much improved image lag, but has the problem of a noisier image being produced. As a consequence CCDs are now the method of choice, which benefit also from a superior sensitivity. (Dowsett & Kenny, 2006, p. 264)

As Fluoroscopy has a need for fast exposures, Grid-Controlled x-ray tubes are used. "The focussing cup in the cathode assembly is maintained a few hundred volts negative with respect to the filament. In this condition the negative potential of the focussing cap prevents the flow of electrons from filament to target. Only when the negative potential is removed can electrons flow across the x-ray tube. This is applying and then momentarily removing the potential difference between the focussing cup and the filament provides an off-on switch." (Hendee & Ritenour, 2002, p. 82) This is not a requirement in imaging systems such as dental do not have a requirement for fast exposures as the anatomy is static. The ability to pulse the x-ray also leads to significant dose reduction for the patient (Dowsett & Kenny, 2006, p. 379) as the exposure times for the patients are less. Keeping the exposure as low as practicable, ensures compliance with the Ionising Radiation (Medical Exposure) Regulations 2000.

Within the Fluoroscopy x-ray tube the anode angle used is 12˚- 8˚ (Dowsett & Kenny, 2006, p. 268). This is comparatively small compared to that used in mammography which utilises a 22˚ anode angle (Fetterly & Schueler, 2003, pp. 1843-1854) A smaller anode angle means that the anode heel effect is less of a factor as a minimal amount of x-ray attenuation is occurring through the anode. This can be a desired factor when differing amount of beam hardness are required for the imaging of varying amount of tissue as in mammography (Jacobsen, 2001, p. 10) A small anode angle is required as the examinations only require a small coverage area, i.e. the whole chest would not have to be examined on one image acquisition. "It is for this reason that radiotherapy tubes use target angles of 35˚ in order to cover large areas of patients at short distances." (Ball & Moore, 2004, p. 177) The small anode angle also leads to less heat occurring on the anode as a consequence the x-ray tube has a no need for a high heat capacity, which is generally is around 1 MHU (Bushong, 2004, p. 375). The low heating effect to the x-ray tube is also due to the exposure factors used, the tube current being is operated is at 3-5mA (Callaway, 2002, p. 41), compared to mammography which uses 25-35mA (Jacobsen, 2001, p. 9). "The tube potential is commonly regulated in ranges from 75 to 90 kV" (Toshiyuki & Satou, 2007, p. 901) compared to that of mammography which is 20-35 kVp (Bushong, 2004, p. 231). Fluoroscopy uses a higher kVp to enable more penetration of the x-ray beam, which is not needed in mammography due to the imaging of soft tissue only. The low heat generated by the anode means that the anode can be a stationary device (Collins, 2001, p. 3). Unlike other radiographic procedures which use higher exposures such as Computed Tomography which require a rotating anode to prevent the disc from other heating and damage occurring. The generator for fluoroscopy in general use is a single phase high frequency generator such as the 'C-Arm MTHF' (Electronic Heestel, 2008). There is not a need for the adoption of a high frequency generator as a low frequency generator would be more than adequate to deliver the maximum 2000W power a fluoroscopy unit requires, however a high frequency generator is significantly cheaper and smaller in size (Dowsett & Kenny, 2006, p. 268). Due to the relatively low power requirements of the fluoroscopy equipment a precision DC power supply could be used, making a fully mobile, battery powered system perfectly feasible. A low frequency generator would be impossible for the needs of Computed Tomography that has high power consumption for the operation of the constant x-ray generation and the added factor of tube cooling to take into consideration.

Fluoroscopy offers two focal spot sizes this is to enable a magnified view to be available without image un-sharpness affecting the required level of special resolution required. "A small focal spot size of not greater than 0.3 mm is necessary for the spatial resolution requirements of small vessel magnification radiography." (Bushong, 2004, p. 375) The focal spot sizes of 0.3 mm and 1 mm also enable the most efficient thermal capacity for the fluoroscopic x-ray tube (Dowsett & Kenny, 2006, p. 268). Conversely, the focal spot of a typical computed tomography system is 1.6 mm to 1.2 mm, with the maximum power being only 40kW (Dowsett & Kenny, 2006, p. 383). Fluoroscopy equipment with its comparatively lower power consumption can adopt a larger focal spot without damage occurring to the anode through excessive heating.

Collimation in fluoroscopy is generally by Automatic to field size with a manual setting also manual (kcare, 2007, p. 18) The fluoroscopic beam has a maximum area that is the same as that of the image receptor in use. If there is a change in film to focus distance the collimation is automatically adjusted too. (Victorian Government Department of Human Services Melbourne, 2007, p. 8) This is unlike intraoral radiography that has no automatic system for collimation for film to focus distance, or a maximum collimation setting for the size of image receptor, which is due mainly as the image receptor cannot be a static device, it is placed into the oral cavity of the patient. The use of automatic collimation aids in compliance with the Ionising Radiation (Medical Exposure) Regulations 2000. To ensure that doses are kept as low as reasonably practicable.

The TV display of a fluoroscopy system is vital. Without the correct setting of brightness and contrast the diagnostic quality of the images can be compromised. By having the brightness on the monitor at too low a setting the operator my feel the need to increase the intensity of the x-ray beam, and in doing so increase dose to both patient and operator. A monitor should never be adjusted after it has been correctly set. "Many systems have automatic brightness control that is designed to rapid increases in operating kilovoltages as patient attenuation increases. These units may allow a lower patient dose rate for the same perceived noise but may also result in loss of image contrast due to higher kVp." (Dowsett & Kenny, 2006, p. 271) Automatic Brightness Control is controlled by automatic adjustment of kVp, mA, or a combination of mA and kVp. This system is not used in Direct Dental radiography, but would be of particular benefit for Orthopantomogram, where differing levels of body tissue are required to be penetrated on the same image. The fluoroscopic imaging room will have a number of ceiling suspended monitors in the imaging room to enable images to be viewed such as 'spot films' and the real time image. This enables the operator ease of viewing and increase the efficiency of the examination.

Grids are used within Fluoroscopy. These grids are there to minimise the effects of scatter degrading the image. Grids can come as part of the machine, dependent on manufacturer the grids may be able to be; disabled; removed (such as the Toshiba DUA-450A); or be only permanently enabled. "The presence of grids in x-ray systems primarily increases the contrast and hence the image quality; however, they increase the dose to the patient and staff by a factor of two or more. Studies have shown that, especially in paediatric cases, removal of the grid has resulted in dose reduction of up to one-third to one-half with little or no degradations in contrast and image quality. Grids should be used with discretion when fluoroscopic examinations are performed on children." (Mahesh, 2001, p.

1033) For certain examinations where diagnostic pathways of fluoroscopy or computed tomography could be used it may be more beneficial for a fluoroscopic examination for certain patients such as bariatric patient, as there will be an increased likelihood of scatter degrading the image. The grid can aid in the minimisation of the scatter, where as computed tomography does not utilise a grid.

Radiation protection during fluoroscopy is maintained during a screening session. There are two methods for screening; undercouch (x-ray tube below table); and overcouch (above table). In both case the operator is protected initially by the tube housing immediately surrounding the x-ray tube. A lead impregnated rubber curtain surrounds the path of the x ray beam to afford more protection to the operator. The operator will also be wearing a lead impregnated rubber apron and wearing lead impregnated rubber gloves (0.25mm lb equivalent). Additionally another radiographer will be stood behind a static protective screen, and also be wearing a lead equivalent apron(0.5mm lb equivalent). Fluoroscopic timing alarms are used to prevent over exposure to a patient. (Ball & Moore, 2004, p. 343) A dead man type switch is also used for exposure control. The use of alarms and dead man switch aid in compliance with Ionising Radiation (Medical Exposure) Regulations 2000, and the dose should be as low as reasonably practicable. The static barrier for the operator is a requirement because of the high dose examinations being used, this cannot be ideal for the patient as it can lead to a feeling of apprehension. This is unlike DEXA, where no barrier is required as of the lower dose, and this can lead to much improved patient experience.

The table construction for fluoroscopy is made of carbon fibre, with metal supports running down the side to provide extra support to the table and minimise any flex in the table. Most modern table are now coming with high loading capacities often as high as 600lbs and tilt functions up to 500lbs. These tables also cater for larger patients by providing a large distance between table and image receptor. (Siemans Healthcare, 2008) "x-ray tube and image receptor are connected with a c arm to keep the appropriate distance apart, regardless of the movement of the equipment." (Callaway, 2002, p. 41) The use of a C arm means there is a need to have sufficient clearance for larger patients. The table's carbon fibre construction is essential, due to its high strength, and its in-ability to significantly attenuate the x-ray beam. The table tilt function makes the table ideal during barium examinations where the patient is required to be manoeuvred into a number of different positions, which is not required in general radiography. The table is cable of being tilted up to 90˚, this is unlike a Computed Tomography examination where the table cannot be tilted laterally, and vertically only approximately 25˚.

Conclusion

Fluoroscopy is moving forward with the introduction of new cutting edge technologies resulting in reduced dose to both patient and operator. There continues to be a need for fluoroscopy, whether it is within the operating theatre or the interventional radiology suite. There are other imaging modalities that are capable of adequately performing the tasks that fluoroscopy is used for, however they do not offer the synergy of benefits that fluoroscopy can afford. With the introduction of digital developments, and the use of image intensifiers, fluoroscopic equipment meets all the requirements of any legislation and guidelines. Fluoroscopy is a technology that is here to stay and, will only increase in its use within the imaging department.

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