Comparative study of skimmed milk as an alternative contrast media on barium swallow examination

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ABSTRACT: This experimental study focused on the viability of skimmed milk as an alternative contrast medium for barium swallow examination, Quality of radiographic images produced using barium sulphate and those of skimmed milk as contrast media were compared and assessed by radiologists using parameters of density, contrast, contrast and spatial resolutions. Participants of the study were 20 patients who consensually agreed to be part of the study. Statistical tools used were weighted mean and t-test. Findings of the study showed that radiographic images produced using barium sulphate were generally rated as very satisfactory while those which used skimmed milk as contrast medium had poor ratings. T-test test showed significant differences in assessments on radiographs with barium sulphate consistently rated high in radiographic quality. As a benchmark study, a deeper follow-up study may be conducted to determine intervening factors and reasons why skimmed milk may not be used as an alternative contrast medium.

Keywords: barium sulphate, skimmed milk, contrast media, barium swallow procedure.

INTRODUCTION

Medical imaging aims to diagnose and examine diseased tissues by creating images of the internal structures of the body. It provides the necessary information which will guide doctors on the appropriate treatments that should be done (De la Vega, 2014). Radiographic procedures are then used. Conventional radiographic procedure has a beam of X-rays which passes through a target object and exposes an underlying photographic film. The developed film then provides an image of the radiodensity pattern of the object. Less radiodense areas produce

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a greater blackening of the film; more radiodense, bony tissues produce a lighter image.

As required in imaging procedures, the quality of image produced should have the appropriate contrast, density, contrast and spatial resolutions so that the damaged tissues may be delineated. Radiographic density (AKA optical, photographic, or film density) is a measure of the degree of film darkening. Technically, it is called transmitted density because it is a measure of the light transmitted through the film. Good spatial resolution is important in films; when it is good, the image shows the smallest discernible detail in an image making medical decisions more valid. Spatial resolution allows comparisons of two different types of images to see that which one is clear or which one is not. Contrast is another required quality of radiographs .High contrast films have few shades of gray, Low kVp technique, short scale of contrast, have a short or narrow window width; on the other hand, low contrast films have many shades of gray, high kVp technique, long scale of contrast, have a large or wide window width.

The controlling factor has the most direct effect on the image. Kilovoltage peak (kVp) is the controller of contrast. As kVp increases contrast decreases. Contrast resolution enables radiologists to distinguish between differences in intensity in an image. Poor contrast resolution makes medical imaging difficult as radiologists cannot define the image (Bushong, 2013).

Contrast agents are useful adjuncts in radiological imaging because they make it possible to determine the location, size and shape of organs or other structures of the body in the context of their surrounding tissues. Radiography procedures detect and map differences in the composition of a target anatomical part and can therefore be used to differentiate between normal tissue and tumors, lesions, or blockages. Small tumors and overlapping tissues, however, are difficult to distinguish and identify and thus, a contrast agent which enables definition of volumes and delineation of boundaries is used for the purpose. As cited by Aspelin et al., contrast media enhance the differences seen between the body tissues on the images.

Contrast media may be used with all of these imaging techniques to enhance the differences seen between the body tissues on the images. Contrast media alter the response of the tissues to the applied electromagnetic or ultrasound energy by a variety of mechanisms. The ideal contrast medium would achieve a very high concentration in the tissues without producing any adverse effects. It is a chemical that is used in x-ray, computed

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tomography, magnetic resonance imaging and in ultrasound imaging. It makes the image lighter and darker, in other words, contrast media make the images clearer and more visible. Unfortunately, so far this has not been possible and all contrast media have adverse effects (Baert et al., 2006).

Radiographic contrast media are divided into positive and negative agents. The positive contrast media attenuate x-rays more than do the body soft tissues divided into water soluble iodine agents and non-water soluble barium agents. Negative contrast media attenuates x-rays less than do the body soft tissues; however, no negative contrast media are commercially available (Baert, Sartor & Thomsen, 2006). Advances in this field promise to facilitate early diagnosis, identify the stage of a disease and provide fundamental information about pathological processes, so that diagnostic and molecular imaging could also be applied to follow-up the efficacy of a specific therapy (De La Vega & Hafeli, 2014).

Effective contrast agents for X-ray may be either less radiodense than body tissues or more radiodense. The less radiodense agents include air and other gases; an example of a more radiodense contrast material is a barium sulfate suspension.

Barium sulphate commonly referred to as barite, is suitable for many diverse uses because of its high specific gravity opaqueness of x-ray inertness and whiteness. It is mainly used as radio contrast agent, filler in plastic, extender in paints and an additive in pharmaceutical products and printing ink (Ramaswamy, Vimalithithan & Ponnusami, 2011). Barium sulphate is in a class of medications called radiopaque contrast media. It works by coating the esophagus, stomach, or intestine with a material that is not absorbed into the body so that diseased or damaged areas can be clearly seen by x-ray examination. Mixed solvent system has been found as an excellent method for the preparation of well dispersed barium sulphate nano particles (Ramaswamy, Vimalithithan & Ponnusami, 2010).

A barium swallow is a special x-ray to look at the oesophagus, (the tube connecting the mouth to the stomach). A barium meal is a special x-ray to look at the stomach. In this test, the patient drinks some barium liquid; the barium liquid is fruit flavoured and is not unpleasant to drink. The patient stands in front of an X-ray machine and pictures are taken as the patient swallows the drink. The barium coats and outlines the oesophagus and the stomach on the x-rays (NHS Foundation Trust, 2015). The barium swallow is used to look for problems in

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the oesophagus such as narrowing, hiatus hernia, tumours etc. This test takes approximately 10 minutes. The test allows the Doctor to best plan the patient's treatment.

Despite the acceptance of the barium swallow, NHS Foundation Trust (2015) reminds the patient to ask the doctor about the amount of radiation used during the procedure and the risks related to the particular situation. For instance, patients who are allergic to or sensitive to medications, contrast dyes, iodine, or latex should consider the risks and constipation or fecal impaction may occur if the barium isn't completely eliminated from the body. Also, contraindications for a barium swallow may induce esophageal or bowel perforation, severe swallowing difficulty such that aspiration (entry of substances into the lungs) of barium is likely. Bowel obstruction or severe constipation may also be experienced by the patient (http://www.hopkinsmedicine.org).

Moreover, there are problems with clinically used contrast agents one of which is they only provide limited contrast, which can lead to inaccurate diagnoses. Other medical imaging techniques, such as magnetic resonance imaging (MRI), positron emission tomography (PET), single photon emission computed tomography (SPECT) and optical imaging face the same problem. Despite the differences between them, the use of multimodal imaging agents makes it possible to combine some of these techniques into a single scan to enhance the accuracy of diagnoses by utilizing information obtained from each one (De La Vega & Hafeli, 2014). However, contrast media have limited capability to see soft biological tissues due to lack of sufficient contrast.

In view of the cited issues on accepted protocol such as use of barium sulphate and due to some other medical issues on time release there are efforts to find and work on alternative contrast media which may provide similar accuracy as conventional standard contrast media in disease prognosis but with lesser safety issues.

For instance , an invention related to a non-aqueous fluorocarbon composition for use in magnetic resonance imaging (MRI) or radiographic imaging (X-ray or computed tomography), particularly imaging of the gastrointestinal (GI) tract; an improved fluorocarbon composition with enhanced contrast effects in the GI tract; a fluorocarbon composition having improved palatability; a fluorocarbon composition for delivering drugs or bioactive agents; improved preparations for radiographic imaging or MRI; methods for producing and using such preparations; methods for improving

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the palatability of non-aqueous liquids; and methods for improving imaging had been applied for patenting (US 6420436 B1).

On a related concern, as part of research at Nanoprobes, researchers have investigated the potential of gold nanoparticles as improved X-ray contrast agents, It was reported that gold nanoparticles may overcome many of the limitations of conventionally used contrast agents. Gold has higher X-ray absorption than iodine with less bone and tissue interference, thus achieving better contrast with lower X-ray dose. Because nanoparticles clear the blood more slowly than iodine agents, they permit longer imaging times (Nano Probes e-news, 2006).

A study parallel to this study was geared to experimenting on the feasibility of skimmed milk as a contrast agent as it was found to have luminescence which may be helpful in delineating structures and possibly show difference of esophageal structure as against its surrounding tissues . Susman (2006) presented milk appears to be a viable alternative to VoLumen, a generic name of barium sulfate as a contrast agent for radiological studies of the abdomen. According to study, "Milk costs less, is favored by patients, and causes fewer abnormal symptoms in patients undergoing these procedures." For the study, 62 patients were assigned to drink VoLumen before undergoing abdominal/pelvic CT scans, and their images were compared with those of 102 patients who drank 4¼ cups of 4% whole milk, Of the patients who took VoLumen, 40% would have preferred milk, while 85% of the patients on milk said they would select milk again in another study. Factors of health, cost-benefits, and palatability seem to be some reasons for more studies conducted that focus on milk as a viable alternative to other contrast agents.

Rupa, Al Azad & Chakraborti (2013) reported whole milk is comparable to iopamiro with respect to bowel distention and gastrointestinal tract discrimination and better in bowel wall visualization and has better patient acceptance, and fewer adverse symptoms. Milk is a cost-effective alternative to iopamiro as a low-attenuation CT oral contrast agent.

Milk contributes substantially to nutrient intake. Those who consumed milk had higher intakes of several key nutrients. Milk provides more than 50 percent of the daily intake of vitamin D, over 30 percent of calcium, and over 20 percent of vitamin A, riboflavin, vitamin B12, and phosphorus for milk. According to the 2010 USDA Dietary Guidelines for Americans a nutritious choice – unlike many soft drinks and fruit juices, flavored milk provides at least 8 grams of protein per serving and essential nutrients such

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as calcium, vitamin A, D, B12, potassium, phosphorous, riboflavin, and niacin. This unique nutrient profile along with small amounts of sugar added to nutrient-dense foods, such as reduced fat milk products, may encourage intake of such products by improving their palatability, fostering increased nutrient intake without excessive calories (Verruma-Bernardi, Lee, Palchak & Bordi 2015). As a contrast agent, it may provide health and acceptable taste to those who would intake it in the barium swallow procedure.

Whole milk contains vitamins (principally thiamine, riboflavin, pantothenic acid, and vitamins A, D, and K), minerals (calcium, potassium, sodium, phosphorus, and trace metals), proteins (which include all the essential amino acids), carbohydrates (chiefly lactose), and lipids (fats). (Pavia, Lampman, Kriz, Engel &Saunders, 2000). It does not easily dissolve or fade inside the GI tract. It is also easy for patients to follow instructions because of the enjoyment of the chocolate milk. It is also nutritious for the patients for it contains calcium and Vitamin A.

Considering such potentials, the main objective of this study is to investigate if skimmed milk can be used as an alternative contrast medium for use in barium swallow examination and have the potential to perform as barium sulphate in the radiograph. Because of the essential use of contrast media in various special procedures such as barium swallow, the researchers believe that this experimental study may provide benchmark data on an alternative contrast medium and be contributory to the data bank on experiments on alternative barium swallow agents.

MATERIALS AND METHODS

Research Design

The study was experimental in nature which involved preparation of contrast media of barium sulphate and skimmed milk solutions utilizing them in radiographic procedures and determining which would produce clearer and better radiographic images. The experiment was conducted at LPU-Batangas, radiology department at Mabini 101 last September to October 2015.

Participants of the Study

Twenty male participants ranging from 18 years old and above consensually participated in this experimental study. The

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inclusion criteria for participants were that the participants should be male with sthenic body habitus 18 years old and above with no esophageal ailments. The exclusion criteria were minor, female participants experiencing dysphagia and with hypersthenic, hyposthenic and asthenic body habitus.

Of the twenty male participants, ten each were given barium sulphate solution and the other ten took skimmed milk as contrast medium for their barium swallow examination.

Preparation of barium sulphate

The barium sulphate (E-Z HD, E-Z_EM Canada Inc. for E-Z-EM,Inc.) was prepared according to manufacturer's instruction. A 65ml of water was added to the E-Z-EM bottle and lid was secured the bottle. Invert the bottle and tapped with fingers to mix contrast into the water. The bottle was shaken vigorously for 30 seconds. After five minutes, the bottle was then reshaken thouroughly. This yields 136 ml of suspension, 85% w/w, 250 w/v. The solution prepared was 4:5 with four tablespoons barium sulfate diluted with five tablespoons of water.

Preparation of skimmed milk

Scout phase. Before conducting the experiment to the participants, different kinds of possible contrast media were tested including milk - sterilized, powdered, evaporated, fortified, condensed, pasteurized and skimmed milk which were exposed to x-rays. Of these, only the skimmed milk showed an image on the radiograph. It could be because skimmed milk has the lowest fat content and has the highest calcium content. Calcium in bones absorbs x-rays the most, so bones look white. Fat and other soft tissues absorb less, and look gray. Air absorbs the least, so lungs look black. Thus, skimmed milk was considered to be used as test contrast medium for the examination.

Several trials were conducted to determine the appropriate concentrations to be used. In the first trial, 50ml of skimmed milk was poured to a plastic cup. Two patients were asked to drink a mouthful while exposing them to x-rays. The result looks like a plain Right Posterior Oblique position of the lungs.

On the second trial, three tablespoons of skimmed milk powder were added to the skimmed milk used to have a thick mixture to slow down the deglutition and for it to properly coat the esophagus. This solution was tried to three patients. The result was the same as to the first trial.

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On the third trial, the same skimmed milk mixture used in trial 2 was used but this time, the technical factor used had 5 kvp and 3 mAs added. To strengthen the penetration factor of x- rays. This was tried to two patients. The results showed slight changes as the densities on the tissue and bones started to thickened according to our own observation.

For the fourth trial, the same mixture of skimmed milk used in trial 2 and trial 3 were used but this time, the technical factor used was 10 kvp and 5 mAs. To strengthen the penetration factor of x- rays. This was tried to three patients. The result was the same as to the third trial.

The final technical factor was 78 kVp and 7.0 mAs.

For the skimmed milk solution, the researchers used "Harvey fresh skimmed milk".

Procedures

For barium sulphate. A barium swallow procedure was performed using a 14x17 in radiographic cassette containing a radiographic film. The patient was asked to stand upright facing the x-ray tube with the body oblique 45 degrees to the right forming an antero-posterior oblique position with an AP projection. The VCH (vertical cassette holder) containing the cassette was centered to the body of the patient. Central ray was perpendicular to the xiphoid process. The patient was instructed to swallow the barium sulphate solution as contrast medium. After three seconds, the patient was exposed to x-rays. After the exposure, the film was processed with the use of the automatic processor. This procedure was given to ten males who passed the inclusion criteria as participant of the study.

For skimmed milk. The same procedure was done using skimmed milk as contrast medium to another set of ten male participants who likewise passed the inclusion criteria to be a research participant in the study.

Evaluation of Results

The 20 radiographic images which used the barium sulphate and skimmed milk as contrast media were presented to three radiologists who studied the radiographs according to the quality criteria of contrast, density, contrast resolution and spatial resolution. Consultations with them as to results of their readings were done.

The assessments were given scalar values of 1 to 5 with 1 as lowest criterion to 5 as highest value. The scale continuum

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used was the following: 1-Poor, 2-Fair, 3-Good, 4-Satisfactory and 5- Very Satisfactory.

Statistical Treatment

Weighted mean. This was used to assess the quality of radiographic images considering their qualities of density, contrast, contrast resolution and spatial resolution

T-test. This was used to determine significant difference on the assessments of radiologists on the quality of radiographic images which used barium sulphate and skimmed milk as contrast media considering their qualities of density, contrast, contrast resolution and spatial resolution.

RESULTS AND DISCUSSION

The researchers subjected the radiographic images which were tested using contrast agents, barium sulphate and skimmed milk for evaluation of radiologists to determine differences in their density, contrast, spatial resolution and contrast resolution. Results illustrated in the following figures will also show if skimmed milk may be an alternative contrast medium.

Presented below are the sample radiographic image of skimmed milk and barium sulphate

Figure 1. Radiographic image of skimmed milk that was not ingested

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Figure 2. Radiographic image of barium swallow using barium sulphate

Figure 3. Radiographic image of barium swallow using skimmed milk

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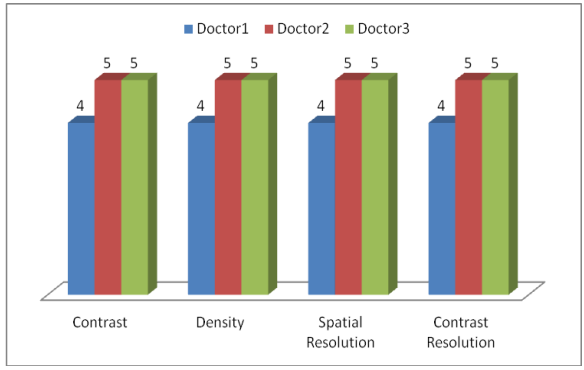
Assessment of the Radiographic Image using Barium Sulfate Solution as Contrast Medium

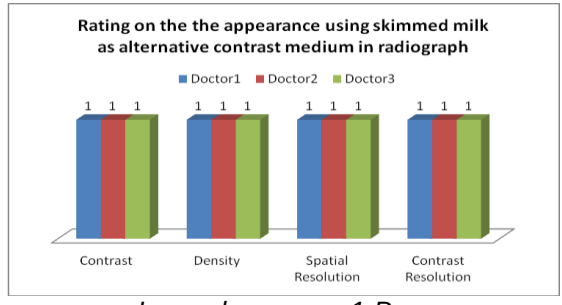


Legend: 5-Very Satisfactory
4-Satisfactory

Figure 4. Radiographic Image Assay using Barium Sulfate as Contrast Medium

Results of the radiologists' evaluations show that generally, the image was cited to have very satisfactory contrast, density, spatial resolution and contrast resolution. While one radiologist differed in assessment, still the assessment showed that the radiograph was given satisfactory evaluation.

Assessment of the Radiographic Images using Skimmed Milk as Alternative Contrast Medium



Legend: 1-Poor

Figure 5. Radiographic Images Assay using Skimmed Milk as Contrast Medium

From the assay of the radiologists on the produced radiographs utiliing skimmed milk, it could be noted that there was consistency in their assessments that the radographs produced

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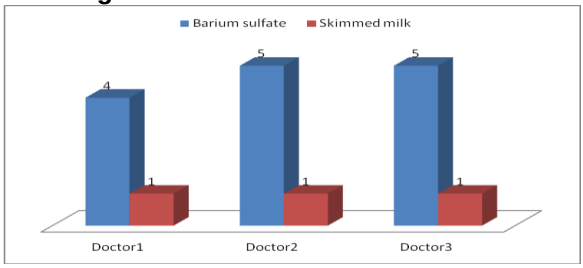
showed poor contrast , density, spatial resolution, spatial resolution as well as contrast resolution, respectively.

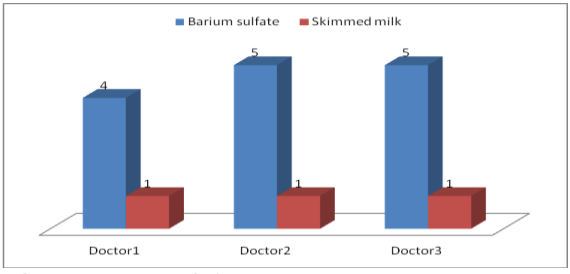
Significant Difference on the Assessments of Radiologists on Radiographs using Barium Sulfate and Skimmed Milk



Legend: 5-Very Satisfactory
4-Satisfactory
1-Poor

Figure 6. Comparison of Assessments on Contrast of Radiographic Images using Barium Sulfate and Skimmed Milk as Contrast Media

Data from the radiologists' comparative assessment of radiographs using barium sulphate and skimmed milk show wide discrepancies on their assessments which evidently showed much higher assessments on contrast on images which were produced using barium sulphate with skimmed milk given poor rating on contrast quality.



Legend: 5-Very Satisfactory
4-Satisfactory
1-Poor

Figure 7. Comparison of Assessments on Density of Radiographic Images

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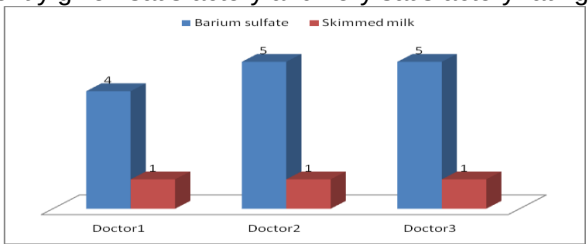
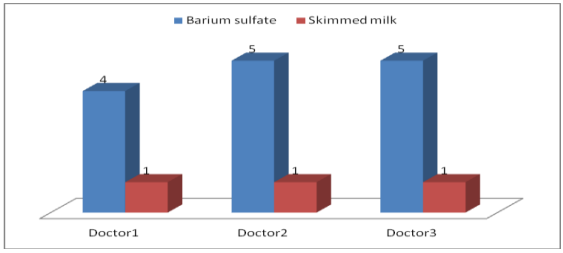
As presented in the figure, the radiologists assessed the poor density of the radiographs where skimmed milk was used while radiographs' density using barium sulphate were consistently given satisfactory and very satisfactory ratings.



Legend:5-Very Satisfactory; 4-Satisfactory; 1-Poor

Figure 8. Comparison of Assessments on Spatial Resolution of Radiographic Images using Barium Sulfate andSkimmed Milk as Contrast Media

Figure 8 shows the spatial resolution assessments of radiologists on radiographic images utilizing barium sulphate as contrast medium were consistently rated as satisfactory and very satisfactory with poor ratings given to skimmed milk as contrast medium.



Legend:5-Very Satisfactory; 4-Satisfactory; 1-Poor

Figure 9. Comparison of Assessments on Contrast Resolution of Radiographic Images using Barium Sulfate and Skimmed Milk as Contrast Media

The radiologists likewise described the contrast resolutions of radiographic images which used barium sulphate as satisfactory and very satisfactory; on the other hand, skimmed milk produced images deemed of poor quality by the radiologists.

T-test test for homogeneity was used to statistically test differences on the assessments of the radiologists on the radiographic images.

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Table 1. Test for Significant Differences on Assessments between the Radiologic Quality of Images Produced utilizing Standard Barium Sulfate and Skimmed Milk

Parameters	p-values	Computed values	Decision on Ho	Verbal Interpretation
Contrast	.00	28.174	Reject	Significant
Density	.00	28.174	Reject	Significant
Spatial Resolution	.00	28.174	Reject	Significant
Contrast Resolution	.00	28.174	Reject	Significant

Results of hypothesis testing showed significant differences on radiologists' assessments on quality of radiographic images as reflected in computed values of 28.174 in parameters which were higher than the p-values of .00 of all parameters. The null hypothesis was rejected.

DISCUSSION

This study was undertaken to test the viability of using an alternative contrast media to the conventionally used barium sulphate solution in barium swallow examination. The results of the radiologists' assay show that the conventional barium sulphate solution produced very satisfactory radiographs. It could be inferred that barium sulphate enabled differentiation and visualization of the tissue under study providing clearer images and therefore leading to correct prognosis .This means that barium sulphate as an imaging modality very sufficiently produced the required clarity and quality to visualize the conformation of the esophagus in the context of its surrounding tissues (Aspelin et al.) which are features of functional quality radiographs. These qualities were evident in the radiographs produced in this study where barium sulfate was used as contrast medium. As cited in Bushong (2013), quality radiographs should have contrast, density and the spatial and contrast resolutions which should enhance and show clarity of image or anatomy which should be visualized.

This experimental study tested the feasibility of using skimmed milk as contrast medium , The encouraging factor was that during the scout phase on tests of variants for a possible contrast medium , among them , only skimmed milk gave encouraging an point to further explore its possibilities as a contrast agent as it showed an image when exposed to x-rays. Moreover, the studies of Pavia, Lampman, Kriz, Engel

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&Saunders, (2000), Verruma-Bernardi, Lee, Palchak & Bordi 2015It Rupa, Al Azad & Chakraborti (2013) reported benefits of milk to health and palatability which the researchers believed would be an added feature benefit of use of skimmed milk which would lessen the toxicity and health risk issues of barium sulphate. . Susman (2006) presented milk appears to be a viable alternative to VoLumen, a generic name of barium.

However, results revealed the radiographs which used the skimmed milk as contrast medium poorly produced the required clarity to suffice them to detect the esophagus. Despite the variants on concentrations and adjustment of technical factors of kVp and mAs, the skimmed milk was not able to provide the appropriate image which is relevant to have a good reading of the conditions of the esophagus.

It was noted that the images' clarity were poor due to their low attenuation; the skimmed milk did not allow presentation of clear details of the esophagus making them indiscernible. The contrast resolution was poor and thus, the radiologists found the medical imaging to quantify the quality of the acquired images difficult to define (Gonzalez, Woods - 2nd Edition).

Consultation with a radiologist provided information that skimmed milk is faintly radiopaque so that in UGIS films , the contrast in the soft tissue and bone density was not clear thus making skimmed milk not suitable as a contrast media . The skimmed milk density was not able to discern the soft tissues and the bone .

This explains the poor ratings given in the assessments of the radiologists on the radiographs produced using skimmed milk as contrast medium. This further shows that barium sulfate is still the most viable and functionally acceptable contrast agent for barium swallow examination procedure.

CONCLUSION

The experimental study affirmed barium sulfate impacts the quality of images produced in a barium swallow procedure indicating it provides the contrast necessary to produce clear radiographic images . On the other hand, skimmed milk when tested as feasible contrast medium poorly provided the required images .

RECOMMENDATIONS

The study generated poor results ; however, as this is a benchmark study , a deeper study may be conducted to determine

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intervening factors such as anatomic number, technical factors and reasons why skimmed milk may not be used as an alternative contrast medium

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