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ORIGINAL PAPER

Can we use pulsed fluoroscopy to decrease the radiation dose during video fluoroscopic feeding studies in children?

M.D. Cohen*

Department of Radiology, Riley Children's Hospital, Indiana University School of Medicine, Indianapolis, Indiana, USA

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AIM: To investigate whether it is possible to reduce the radiation dose during video fluoroscopic feeding studies below the current 30 frames/s (continuous fluoroscopy).

METHODS: Ten consecutive children who had supraglottic penetration while swallowing barium were evaluated as part of a video fluoroscopic feeding study. All fluoroscopic studies were performed with a pulse rate of 30 frames/s. Frame by frame analysis was performed of the first episode of penetration in each patient to determine on how many image frames the penetration could be detected.

RESULTS: Supraglottic penetration occurred very rapidly. In seven of the 10 patients, full-depth penetration was only seen on one image frame. In no patient was the full-depth penetration seen in greater than two imaging frames.

CONCLUSION: Decreasing the fluoroscopic pulse rate cannot be used as a method of decreasing radiation dose during performance of video fluoroscopic studies because it will potentially result in non-detection of episodes of supraglottic penetration of liquid barium.

Introduction

Video fluoroscopic feeding studies are commonly performed in children to evaluate potential feeding dysfunction. Because these studies evaluate many swallows, with different food items and consistencies, they often require a large amount of fluoroscopic time; therefore they can deliver large radiation doses to the patients. In one recently reported study of 80 children, the mean fluoroscopic time was 2.48 min.[1] These authors also reviewed the literature and found reports of fluoroscopic times for a feeding study up to 8 min.[1] There is currently a very appropriate major initiative to keep radiation doses in children as low as reasonably achievable.[2] In a recent American College of Radiology white paper on radiation safety, Amis *et al*. state that ''It is incumbent on the radiologist to assume the responsibility for their patients' safety with regard to radiation exposure.''[3] They also state that ''Imaging device parameters should be optimized.'' Radiologists have control over many factors affecting radiation dose. One such parameter over which a radiologist has immediate control is the fluoroscopic pulse rate.

Grid-controlled fluoroscopy allows for a decrease in the frequency of radiation pulses.[4] With pulsed fluoroscopy, radiation is not emitted continuously from the x-ray tube, but it enters the patient in the form of short flashes or pulses.[5] Decreasing the fluoroscopic pulse rate allows for a large potential reduction in radiation dose.[5–7] Low frame rate pulsed fluoroscopy would, therefore, seem an attractive option to be used to lower radiation dose during paediatric video fluoroscopic

* Guarantor and correspondent: Department of Radiology, Riley Hospital for Children, 702 Barnhill Dr., Room 1053, Indianapolis, IN 46202, USA. Tel.: +1 317 873 6586; fax: +1 317 274 2920.

E-mail address: mecohen@iupui.edu

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feeding studies. The pharyngeal phase of swallowing is very rapid. Low fluoroscopic pulse rates may not be rapid enough to detect rapidly occurring abnormalities that take place during the pharyngeal phase of swallowing. The objectives of this study were to evaluate whether pulsed fluoroscopy, as compared to conventional continuous fluoroscopy, has the potential for accurately identifying episodes of supraglottic penetration of thin liquid barium, a frequently detected abnormality during the fluoroscopic feeding studies. Supraglottic penetration is defined as entry of contrast into the superior part of the larynx without extension below the vocal cords. Its presence is believed to be an indication of abnormal swallowing with an increased potential for true aspiration through the vocal cords.

Methods

The study was approved by our Institutional Review Board. All studies were performed by the author. The study population was 10 consecutive children, being studied by video fluoroscopic feeding study, in whom supraglottic penetration with barium was observed. The age range was 1 month to 2 years 9 months. All studies were performed with the patients sitting in a foam cradle placed on the footrest of an upright fluoroscopic table. All studies were performed using a Siemens (Erlanger, Germany) fluoroscopic unit. All studies were performed using fluoroscopy at 30 frames/s (so called continuous fluoroscopy). Siemens offers the option of performing fluoroscopy at 2, 8, 12.5, or 30 frames/s. All patients were tested by offering a drink of non-thickened barium.

Supraglottic penetration is seen as a small, thin, finger-like projection of barium extending anteriorly and inferiorly into the vestibule of the larynx, but remaining superior to the vocal cords. The cine loop showing the first episode of supraglottic penetration detected in each patient was saved for analysis. If a patient had more episodes of penetration they were not included in our analysis. The Siemens fluoroscopic machine retains in computer memory the most recent loop of fluoroscopy. As soon as supraglottic penetration was detected, the cine loop was captured and sent to the technologist's review station. On this review station, the cine loop was reviewed, frame by frame, by the author.

For each patient, the number of frames on which full-depth penetration was identified (i.e., a column of barium seen down to the approximate level of the vocal cords) was recorded. We also recorded the number of additional frames on which some barium was partially visible in the laryngeal ventricle, but not to the full depth of the vocal cords.

Results

The results are presented in Table 1. In seven of the 10 patients, full-depth penetration was only seen on one image frame. In no patient was the full-depth penetration seen in greater than two imaging frames. The number of additional frames showing some barium in the supraglottic space (partial penetration) ranged between 0 and 2 (Fig. 1).

Discussion

As previously discussed, video feeding studies may entail many minutes of radiation. This long duration is of concern, as it is a major factor causing relatively high radiation dose to the patients. Many methods may be used to reduce radiation dose to patients during video feeding studies. Study duration should be limited to the maximal extent possible.[1] Other factors that effect dose and that are under the radiologist's immediate control include changing the dose needed at the image intensifier, magnification, and the use of an imaging grid.[1, 8] Lowering the fluoroscopic pulse

Table 1 Number of imaging frames on which supraglottic penetration was detected in 10 patients Imaging was performed at 30 frames/s (''continuous'' fluoroscopy)

Patient number	Number of frames showing full depth penetration of barium i.e. barium extends to the depth of the laryngeal vestibule, just above the vocal cords	Additional number of frames showing partial penetration i.e. some barium still in the laryngeal vestibule
1	1	1
2	2	2
3	1	0
4	1	0
5	2	2
6	2	1
7	1	1
8	1	1
9	1	1
10	1	0
MEAN(range)	1.3 (1–2)	0.9 (0–2)

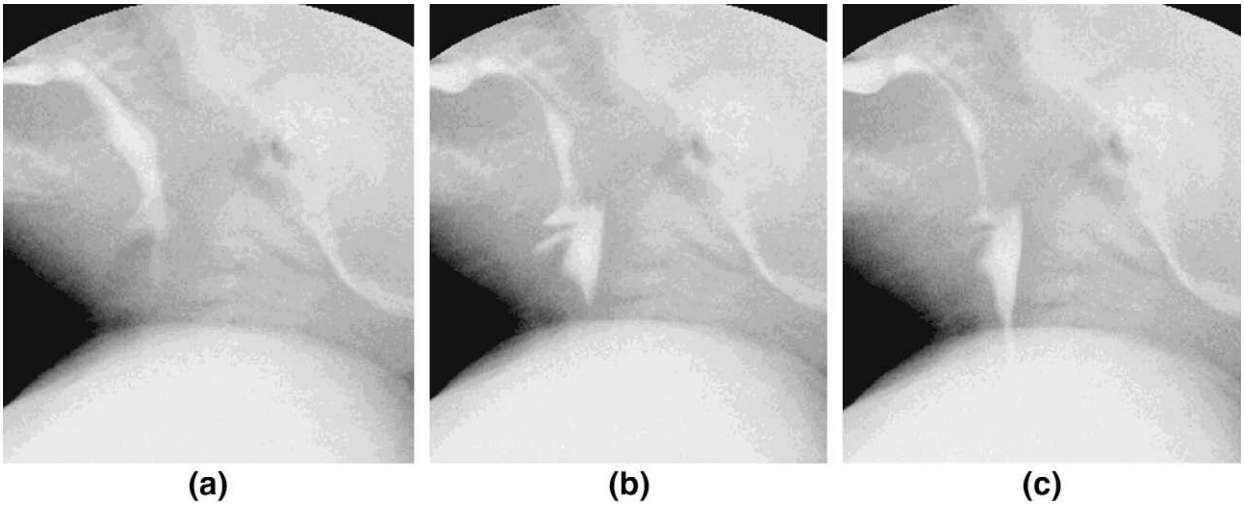

Figure 1 Three frames from a single swallow showing supraglottic penetration. Imaging at 30 frames per second. (a). There is a normal appearance of barium in the pharynx (b). Next frame shows deep supraglottic penetration (c). Next frame shows a tiny wisp of barium still in the laryngeal vestibule. It had cleared completely on the following frame.

rate can result in a very large reduction of the radiation dose.

Pulsed fluoroscopy is now available on new fluoroscopic units provided by most manufacturers. The manufacturers commonly offer the radiologist a choice of four different fluoroscopic pulse rates ranging from a minimum of 2 or 3 frames/s, to a maximum of 30 frames/s (usually termed continuous fluoroscopy by most manufacturers). Our patients were studied with pulse rates of 30 frames/s.

Video fluoroscopic feeding studies are performed to define the nature and pathophysiology of swallowing impairment. They go by several names, including modified barium swallow, video feeding study, and feeding study.[1] These studies are performed with the patient sitting upright. The patients are given a range of age-appropriate food and textures to swallow.[1] Swallowing is observed in the lateral view. The voluntary phase of swallowing involves creation of a bolus of contrast, which is passed into the back of the mouth. As the bolus enters the pharynx, the pharyngeal phase of swallowing is initiated.[9] This is involuntary.[9] The normal pharyngeal phase involves bolus transport from the oropharynx into the oesophagus without entry of the swallowed material into the larynx or trachea.[10] The total pharyngeal phase of swallowing lasts for just over 0.5 s.[10] At very low fluoroscopic frame rates of 2 frames/s, it is conceivable that almost the entire pharyngeal phase of the swallow can occur between fluoroscopic pulses, and thus not be visualized.

During the pharyngeal phase of swallowing, there is a lot of dynamic motion.[10,11] The soft palate closes. The glottis closes. The bolus moves through the pharynx without pooling or delay. The bolus stays intact without streaming. To observe all of these dynamic changes, rapid imaging may be required.[10] Dodds *et al.*, stated that a frame rate of 30 frames/s was required for adequate observation of all of these events.[10]

All of the dynamic phases of the pharyngeal phase of swallowing need to be evaluated by the radiologist when performing a video fluoroscopic study. Aspiration and supraglottic penetration are perhaps the most significant abnormalities sought during radiological examination of the pharyngeal phase of swallowing.[11] Evaluation of supraglottic penetration was chosen because it occurs very rapidly, is an important swallowing abnormality to detect, and because it is easy to evaluate by frame by-frame viewing of the episode of penetration. The term penetration is applied to barium entry into the laryngeal vestibule without passage below the vocal cords. This occurs much more commonly than complete aspiration of barium, which is passage of barium below the vocal cords.[11] Penetration occurs most commonly with swallows of thin barium and is seen as a finger of barium extending into the laryngeal vestibule.[11]

The results of the present study indicate that deep penetration is most commonly only seen on a single video image frame, when performing fluoroscopy at 30 frames/min. There is, therefore, a high risk of missing penetration and under-diagnosing abnormal swallowing if one attempts to reduce the fluoroscopic pulse rate below 30 frames/s. The identification of residual barium, seen as incomplete depth penetration on frames

adjacent to those showing the full penetration, is not seen on enough frames to rely on detection of this abnormality for accurate identification of penetration. Utilization of fluoroscopic frame rates of less than 30 pulses/s could easily have missed or underestimated the severity of supraglottic penetration in the present cohort of patients.

In conclusion, some important swallowing abnormalities, such as supraglottic penetration, occur very rapidly. Decreasing the fluoroscopic pulse rate cannot be used as a method of decreasing radiation dose during performance of video fluoroscopic studies. Attempts to reduce radiation dose by reducing the fluoroscopic radiation pulse rate below 30 frames/s will result in an underestimation of the presence of supraglottic penetration of swallowed liquids. As a result appropriate diet changes, to reduce the risk of aspiration, may not be made.

References

1. Weir KA, McMahon SM, Long G, et al. Radiation doses to children during modified barium swallow studies. *Pediatr Radiol* 2007;**3**:283—90.
2. Stueve D. Management of paediatic radiation exposure rate using Philips fluoroscopy systems exposure rate wise: perfect image, perfect sense. *Pediatr Radiol* 2006; **36**:216—20.
3. Amis Jr ES, Butler PF, Applegate KE, et al. American College of Radiology white paper on radiation dose in medicine. *J Am Coll Radiol* 2007;**4**:272—84.
4. Hahn H, Farber D, Allmendinger H, Brendler J. Grid-controlled fluoroscopy in paediatric radiology. *Medicamundi* 1997;**41**:12—7.
5. Nagel HD. Technical note: dose management. *Medicamundi* 1997;**41**:43—6.
6. Brown PH, Thomas RD, Silberberg PJ, Johnson LM. Optimization of a fluoroscope to reduce radiation exposure in paediatic imaging. *Pediatr Radiol* 2000;**30**:229—35.
7. Hernandez RJ, Goodsitt MM. Reduction of radiation exposure rate in paediatic patients using pulsed fluoroscopy. *AJR Am J Roentgenol* 1996;**167**:1247—53.
8. Cohen MD. Are we doing enough to minimize fluoroscopic radiation exposure rate in children? *Ped Rad* 2007;**37**: 1020—4.
9. Ott DJ, Pikna LA. Clinical and video fluoroscopic evaluation of swallowing disorders. *AJR Am J Roentgenol* 1993;**3**: 507—13.
10. Dodds WJ, Stewart ET, Logemann JA. Physiology and radiology of the normal oral and pharyngeal phases of swallowing. *AJR Am J Roentgenol* 1990;**5**:953—63.
11. Dodds WJ, Logemann JA, Stewart ET. Radiologic assessment of abnormal oral and pharyngeal phases of swallowing. *AJR Am J Roentgenol* 1990;**5**:965—74.