Reducing Radiation Exposure in the Neonatal Intensive Care Unit: How a Process Improvement Plan Can Have Wide-Reaching Effects

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PROBLEM
Ionizing radiation has the potential to cause remote cancers, which represents a risk when using x-rays for medical diagnosis. It has been postulated that radiation exposure from diagnostic medical x-rays in the pediatric age group is significant [1]. Radiation exposure and the potential for radiation-induced cancers have become an important patient safety issue with increasing public awareness. Radiation dose reduction are becoming an important part of radiology process improvement plans particularly in pediatrics [2, 3, 4]. Radiation reduction was the main goal of a process improvement and patient safety plan initiated by the administration and pediatric radiology staff at SUNY Downstate Medical Center. The plan focused on the neonatal intensive care unit (NICU).

BACKGROUND
On February 27, 2011, an article appeared in the New York Times, titled “The Radiation Boom: X-Rays and Unshielded Infants” [5]. The authors, Walt Bogdanich and Kristina Rebelo, described how “This poor, defenseless baby had been over-radiated.” This was the result of including the legs, pelvis, abdomen, chest, and head, called a “babygram,” when performing portable x-rays on almost all neonates in the NICU. The difficulty is that these babies are often premature and are quite small. Therefore, the usual collimation limits of 1 inch can cover a large area of the babies' anatomy.

Neonatologists often gave verbal orders for studies, not appreciating the added radiation dose. For example, the neonatologist could add a verbal order for the abdomen to be included in a chest radiograph. Some of the x-ray technologists would do full baby images (babygrams), assuming that the neonatologists preferred these images. The neonatologists did not complain. This was another source of additional radiation exposure.

The FDA, which regulates medical devices, including x-ray machines, produced guidelines for radiation exposure in medical diagnosis and procedure in a white paper, Initiative to Reduce Unnecessary Radiation Exposure From Medical Imaging [3].

The media attention and government emphasis on radiation safety and developing guidelines on radiation exposure [6-9] previously described created the will and desire at all levels at SUNY Downstate Medical Center to develop this process improvement plan. The administration, from the CEO to departmental administrators, as well as members of the departments of radiology, neonatology, and pediatrics and the nursing staff were involved. The Department of Radiology took the lead in overseeing and implementing the process improvement plan. There was active involvement of the technical staff and the pediatric radiologist. Both the Radiation Safety Committee and the Radiology Process Improvement Committee were involved in the process improvement plan’s development and oversight.

PROCESS IMPROVEMENT PLAN
A 4-point plan was created:

1. A written order mandate was to be enforced. Neonatologists would have to write specific orders for any body part they wanted imaged.

2. Collimation guidelines were reviewed, with newer tighter limits defined. The technical staff was educated as to the new guidelines. Lead collimation lines had to be seen on the image. Digital collimation was not considered adequate. The difficulty lies in the issue of the size of the neonates; they can be very small. A small deviation may expose much of the baby. Thus, new guidelines were developed by a medical physicist, a pediatric radiologist, a neonatologist, and a technical supervisor. These new guidelines included new collimation landmarks, new technical parameters, and education of all staff members who work in the NICU. Collimation parameters were to end the radiation fields at just above the clavicle for the upper field and just above the umbilicus for the lower field and include only the shoulders, not the arms, for the lateral field margins.

3. An informal survey conducted by the director of pediatric radiology found that gonadal shielding was not a hospital policy for NICU patients. Indeed, there was little guidance on how radiographs are ob-
tained in the NICU. Lead shielding was added to the hospital policy for all chest exposures and for male infants when abdominal films were obtained. Gonadal shielding is not used for female infants when abdominal films are obtained because the shield will obscure the necessary anatomy of the lower abdomen. Bismuth shields, which allow visualization of the necessary anatomy and provide some reduction in radiation exposure, were to be considered for all female patients.

4. S values were to be monitored. S values are inconsistent. They are considered an acceptable indicator of radiation exposure when all other technical parameters are kept constant. However, the S value is the only indicator of image exposure with portable equipment. In an effort to create some consistency, all portable machines were calibrated and preset to standards set by the pediatric radiologist and medical physicist. S values were considered in compliance if they ranged from 200 to 800 (per the director of pediatric radiology).

As part of the plan, the burden of oversight fell on the x-ray technologist supervisory staff. Total compliance was measured as “all or none” from the parameters described above. Compliance data were entered into an Excel spreadsheet (Microsoft Corporation, Redmond, Washington) and added to the monthly process improvement dashboard and agenda of both the Radiation Safety Committee and the Radiology Process Improvement Committee. Compliance was followed in this manner indefinitely, with plans to switch to quarterly reporting after 1 year.

RESULTS

Retrospective evaluation was obtained of the data sets for collimation for the month before the beginning of the process improvement plan and prospectively. S values were already a focus from a prior process improvement plan. At this point, the limits were reviewed and discussed with the technical staff. S values had been followed since 2007. Graphs of the compliance data were presented at the monthly Radiology Process Im-

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**SUNY DOWNSTATE MEDICAL CENTER DEPARTMENT OF RADIOLOGY**

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**Fig 1.** Compliance data presented at the Radiology Process Improvement Committee. All data is designated as % compliance. Reprinted with permission, Olatokunboh Osineye, SUNY Downstate Medical Center, Brooklyn, New York.
provement Committee meetings (Figs. 1-4).

With an institution-wide PACS and radiology information system, the written order mandate was easily put in place. All radiology examinations are required to be ordered in the radiology information system before patient information can be entered into the PACS. X-ray technologists must have a radiology information system order before they can perform a portable x-ray study in the NICU. This part of the process improvement plan was not tracked because it became unacceptable to perform x-ray studies without written orders in the system.

The supervisory staff checked daily that lead collimation lines were seen in order to be in compliance. The anatomy present on the image was evaluated as part of compliance. With education and proper monitoring of the technical staff, there was an immediate improvement to the 93% range. At 3 months, additional education and review achieved compliance near 100%, at which it has remained for more than 1 year.

Similar results were seen for gonadal shielding. For boys, the shield was used when abdominal imaging was ordered. When only a chest image was obtained, a lead apron was placed below the diaphragm. Compliance was judged if the lead apron or lead shield could be seen on the radiograph. Within 3 months, compliance reached 99%.

Some S values were out of compliance before the inception of the process improvement plan, despite monitoring. After inception, compliance for S values moved into the 98% range.

Implementation of the plan is a necessary part of the results. The plan was motivated by adverse press. Everyone, from the janitors to the CEO, was aware and talking about the New York Times article [5]. This type of notoriety would be unwanted by any institution performing neonatal x-rays. The negative press and public outcry encouraged involvement at the highest levels of the institution. Administrators from all levels were key motivators. There was participation from multiple departments. The single-mindedness and group cohesiveness were palpable.

**DISCUSSION**
The process improvement plan was developed to reduce radiation exposure in the NICU. Although it was initially motivated by negative media attention [4], the plan has become a model for other hospitals. It was developed with broad support from administrative, clinical, and ancillary staff members. The details of the process changes, devised at our institution and described in this paper, are to be adopted by the New York State Department of Health and Bureau of Environmental Radiation Protec-
tion as a guideline for radiation safety procedures at other institutions (John O’Connell, Bureau of Environmental Radiation Protection, personal communication). In addition, the New York City Department of Health and Mental Hygiene’s Office of Radiologic Health has decided to include inspection of NICUs to review areas outside normal radiology departments in response to recent events (Vincent Parisi, Office of Radiologic Health, personal communication).

This project demonstrates the benefit of teamwork and administrative support. Before this plan, other process improvement plans floundered, including early efforts at limiting S values, as mentioned above. Negative press and attention from top administration provided powerful motivation for everyone to work on this plan, which gave us a joint feeling of purpose.

The project also demonstrates how small changes can have profound effects. This plan was useful for team and confidence building.

This project raises a few questions for consideration regarding quality improvement.

First, does the plan end here? The obvious answer is no. Process improvement is a continuous process. The department and hospital should be looking for other ways to reduce radiation exposure in all patients. Active quality improvement in CT examinations of all children began with the arrival of our pediatric radiologist, with dramatic reduction in the number of examinations performed, as well as reduction in radiation doses.

Second, where does the professional staff’s responsibility begin and end? There are several considerations as to professional responsibility. For instance, why was this problem not already on a process improvement cycle? A new director of pediatrics was hired, with a mandate to lower radiation doses in all pediatric examinations. Although changes had been made to CT scans and work had begun on decreasing radiation doses for other pediatric examinations, these have been slowly implemented. Complexity in management and hospital administration is partially to blame. Supervisory staff members had little encouragement from administration. Neonatologists, who are overburdened with complex medical issues, needed to be educated about the newer concerns regarding radiation use in this population and came into compliance with time. Other issues include decreasing technical staffing because of cuts in funding, causing a loss of expertise in the quality assurance process. All of these issues are complex but should not be overlooked. Because radiologists have the final say on quality, it is up to them to be involved in the long run.

Third, was this a successful process improvement? The answer is
yes. Many elements went into the success of this plan, including full administrative support and a team approach, which involved neonatologists, medical physicists, radiologists, x-ray technologists, supervisory staff members, and radiology administrators. With proper education and teamwork, reasonable achievement of goals is possible. The important point is that it takes more than a supervising radiologist or one person on the team to implement change; change must be global and all encompassing. Oversight by the Radiology Process Improvement Committee was an important part of the plan that allowed process correction when needed and gave the department positive feedback, an essential part of any process improvement plan.

Finally, what are the requirements of a good continuous quality improvement process in a hospital department? What should it look like in the future? These are key questions that should be answered by looking back at some of the positive things to come out of the plan. This plan should be viewed as a model for other plans in the department and the hospital. Active involvement of the administrative, professional, and technical staff is essential for a proper continuous quality improvement program. This is the hallmark of teamwork. Despite how our legal system looks at doctors, doctors are no longer alone in the practice of medicine. Each radiologist should make time to be more active in the department and work more closely with the technical staff to find ways to improve quality and diminish errors. Teamwork does not end in the department. The patient care team includes all persons involved. Radiologists need to think of themselves as part of the bigger patient care team, which means discussing both individual concerns as well as the broader issues of patient safety. This can be very rewarding on the professional and personal levels for radiologists.

CONCLUSIONS

With active support from all levels of a hospital, process improvement plans are easier to enact and maintain. Support from the highest levels of administration, deans, and department chairs must be in place for process improvement plans to be successful.

Teamwork is another important key to the success of a process improvement plan. The team in this plan included nonradiology professional staff members, hospital administrators, radiology professional staff members, and ancillary staff members.

For those institutions with residents, it is important for the residents to take ownership of their interpretations by judging the quality of images they read. They too must be part of the team [9].
REFERENCES


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