Benefits and Safety of CT Fluoroscopy in Interventional Radiologic Procedures

PURPOSE: To determine the benefits and safety of computed tomographic (CT) fluoroscopy when compared with conventional CT for the guidance of interventional radiologic procedures.

MATERIALS AND METHODS: Data on 203 consecutive percutaneous interventional procedures performed with use of CT fluoroscopic guidance and 99 consecutive procedures with conventional CT guidance were obtained from a questionnaire completed by the radiologists and CT technologists who performed the procedures. The questionnaire specifically addressed radiation dose measurements to patients and personnel, total procedure time, total CT fluoroscopy time, mode of CT fluoroscopic guidance (continuous versus intermittent), success of procedure, major complications, type of procedure (biopsy, aspiration, or drainage), site of procedure, and level of operator experience.

RESULTS: The median calculated patient absorbed dose per procedure and the median procedure time with CT fluoroscopy were 94% less and 32% less, respectively, than those measurements with conventional CT scanning (P < .05). An intermittent mode of image acquisition was used in 97% of the 203 cases. This resulted in personnel radiation dosimetric readings below measurable levels in all cases.

CONCLUSION: As implemented at the authors’ institution, use of CT fluoroscopy for the guidance of interventional radiologic procedures markedly decreased patient radiation dose and total procedure time compared with use of conventional CT guidance.

The accuracy and safety of imaging-guided percutaneous needle biopsy, aspiration, and drainage procedures have been well documented (1–4). Because percutaneous intervention is less invasive and more cost-effective than surgery, the number of radiologic procedures performed each year continues to increase. Computed tomography (CT) has remained the modality of choice for guidance in many interventional procedures because of its superior contrast and spatial resolution and ability to image areas not well demonstrated by ultrasonography (US) such as the lung, retroperitoneum, and bone. It is also superior to US in the large patient and when lesions are obscured by bowel gas. At our institution, 947 CT-guided procedures were performed in 1998. This increased to 1,022 in 1999.

CT fluoroscopy is a recently developed acquisition mode that allows faster image reconstruction, near-continuous image update, and convenient in-room table control and image viewing during a CT-guided procedure. In a typical CT fluoroscopy system, cross-sectional CT images are reconstructed at reduced spatial resolution and updated continually at a rate of several frames per second (7 frames per second at our institution) by using a high-speed array processor. These capabilities allow the fluoroscopy system to operate in two common operational modes: continuous (real-time) or intermittent (quick-check). The distinction between the two modes is whether the system is operated continuously during interventional activity or whether it is operated intermittently between interventional actions by the radiologist.

CT fluoroscopy has many potential advantages; two of the most important are the
potential for a decrease in patient radiation dose and the potential for increased procedure efficiency. However, if used improperly (ie, a high current with a prolonged CT fluoroscopy exposure time), CT fluoroscopy has a greater potential for radiation injury to the patient than does conventional CT and also has the potential for considerable radiation exposure to personnel. In 1999, the Food and Drug Administration’s Radiation Safety Standards Committee expressed their concerns regarding CT fluoroscopy (5). These concerns included the difficulty of appropriate regulation of this new application, the potential for high radiation dose to patients and personnel, and the lack of knowledge by the users of this equipment about skin dosage implications. The purpose of our study was to determine the benefits and safety of CT fluoroscopy when compared with conventional CT for the guidance of interventional radiologic procedures.

MATERIALS AND METHODS

Patients and Procedures

Data on 203 consecutive percutaneous interventional radiologic procedures performed by using CT fluoroscopic guidance were obtained during the first 6 months (August 1999 through January 2000) of operation of CT fluoroscopy (HiSpeed CT/I scanner with SmartView CT fluoroscopy; GE Medical Systems, Milwaukie, Wis) at our institution. These data were compared with data obtained on 99 consecutive procedures performed during the same period with use of conventional CT guidance with a conventional spiral CT scanner (HiSpeed; GE Medical Systems). These CT scanners are located at separate sites in our institution. The 302 patients (145 female and 157 male patients; age range, 5–89 years; mean age, 60 years) were assigned to either conventional CT or CT fluoroscopy depending on which hospital site they were at for evaluation. Both inpatient and outpatient procedures are performed at each hospital.

The radiologists and CT technologists performing each procedure completed a questionnaire to collect information regarding CT imaging parameters (tube potential in kilovolt peaks, tube current in milliamperes, section collimation) used in patient dose calculations, identification numbers of single-use personnel dosimetry badges to determine radiation dose to personnel, total procedure time, total CT fluoroscopy exposure time, operational mode of CT fluoroscopic guidance (continuous vs intermittent), success of procedure, major complications, type of procedure (biopsy, aspiration, or drainage), site of procedure, and level of operator experience (resident, fellow, or staff). This study was approved by our institutional review board, and written informed consent was obtained from all patients.

Total procedure time was defined as the time from injection of a local anesthetic to final withdrawal of the biopsy or aspiration needle or placement of the drainage catheter. If a patient required multiple drainage catheters, each catheter placement was treated as a separate procedure. Preprocedural localization time and time for postprocedural scanning to exclude complications were not included in total procedure time. Total CT fluoroscopy exposure time (in seconds) was recorded on the technologist’s monitor and on the in-room videofluoroscopy screen.

The number of procedures performed with use of only the intermittent operational mode, only the continuous operational mode, or a combination of the two modes was also recorded on the questionnaire. When a combination of the two modes was used, the estimated percentage of time spent using the continuous mode versus the intermittent mode was documented.

Success of the procedure as it related to biopsies or aspirations was defined as obtaining sufficient tissue or fluid to allow the pathologist to make an accurate diagnosis or to perform adequate analysis procedures. Biopsies were considered nondiagnostic when there was insufficient tissue for diagnosis or atypical cells only. All positive malignant diagnoses were considered true-positive diagnoses. All positive benign diagnoses and true-negative and false-negative biopsy results were confirmed with repeat percutaneous or surgical biopsy or with 8-month follow-up imaging and chart review. For drainage procedures, success was defined as accurate placement of the drainage catheter in the desired site.

Major procedural complications were defined as those in which the patient developed symptoms or required treatment as a result of the complication. Immediate major complications were documented on the questionnaire by the physician performing the procedure. Patient chart review during 8 months was performed by the principal investigator of this study (S.K.C.). This documented any delayed complications and followed up on any previously noted immediate complications.

Radiologists and radiology residents and fellows performed all of the procedures. Radiology residents and fellows are required to have completed our institution’s radiology physics course, which includes radiation protection and radiobiology instruction. All personnel, including CT technologists, were required to view our radiation safety videotape specifically addressing CT fluoroscopy.

During the procedures, only essential personnel (radiologist, technologist, nurse, and anesthetist) were permitted in the CT suite. All personnel were required to wear a lead apron (0.5-mm lead equivalent) and stand as far away from the CT gantry as feasible. The use of thyroid shields was optional. Only the physician performing the procedure was allowed to operate the x-ray control pedal.

Radiation Monitoring

All radiologists using CT fluoroscopy are required to wear a personal body dosimeter placed at the upper chest level external to the required lead apron and a ring radiation dosimeter on their dominant hand underneath their sterile glove during all procedures. These badges monitored the cumulative personal radiation dose to the radiologist. To obtain radiation dose measurements per procedure for this study, the radiologist was required to wear additional body and ring radiation dosimeters. These badges were distributed just before and collected immediately after each procedure. All exposure results were monitored throughout the study by our institution’s radiation safety department (K.L.C.).

To decrease the potential radiation dose to the hand, radiologists were required to position their hands at least 6 inches from the primary beam when using the continuous fluoroscopy mode. This was achieved by using either a 6-inch or 10-inch sterile stainless steel forceps (operator choice).

At our institution, use of the continuous mode of CT fluoroscopy image acquisition is limited to 90 seconds by institutional policy. If this limit is reached, the procedure may be completed by using only the intermittent fluoroscopy mode. When using the intermittent operational mode, the radiologist is able to step away from the gantry to obtain single exposures.

The CT technologist selected the appropriate tube potential, tube current,
and collimation before each study. The tube potential was set to that used diagnostically for the anatomic region (typically 120 kVp). We used the lowest possible current (milliampere) values that allowed adequate image quality in the region of interest.

Total radiation dose to the patient was calculated from measurements of tube potential, tube current, collimation, number of CT sections (for conventional CT), and total fluoroscopy time and CT dose index (for CT fluoroscopy). Calculations were based on data obtained during the actual procedure; CT fluoroscopy time and number of CT sections obtained during preprocedural and postprocedural scanning were not included. The CT dose index was calculated from quality control measurements performed on a standard 32-cm Plexiglas cylindric phantom that was used to simulate a normal-sized patient. A conversion factor of 0.95 (conversion from air to soft tissue for 100-keV x rays) was used to calculate the estimated maximum absorbed patient dose (6).

Statistical Analysis

Owing to skewness (nonnormality) in the data, results are presented as median with range. Nonparametric tests were used to assess statistical significance. The Wilcoxon rank sum test was used to compare patient radiation dose values and total procedure times between conventional CT and CT fluoroscopy. The Kruskal-Wallis $\chi^2$ test was used to compare total CT fluoroscopy exposure time between procedure types (aspiration, biopsy, drainage) and total procedure and CT fluoroscopy exposure times between operator experience levels (resident, fellow, staff). A $\chi^2$ test was used to compare diagnostic rates. Statistical significance was assumed for $P$ less than .05.

RESULTS

The 203 CT fluoroscopy–guided procedures comprised 146 biopsies, 30 aspirations, and 27 catheter drainages, and the 99 conventional CT–guided procedures comprised 69 biopsies, 18 aspirations, and 12 catheter drainages.

The estimated maximum patient skin dose was significantly lower for all CT fluoroscopy–guided procedures, with a median of 43 mGy versus a median of 738 mGy for conventional CT ($P < .05$) (Fig 1). These numbers show that the median calculated radiation exposure to the patient per procedure with use of CT fluoroscopy was 94% less than that of conventional CT. Data on patient radiation exposure during CT fluoroscopy– and conventional CT–guided procedures are summarized in the Table.

![Figure 1.](image.png)

**Patient Radiation Dose Measurements and Procedure Times for CT Fluoroscopy– and Conventional CT–guided Procedures**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Conventional CT</th>
<th>CT Fluoroscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient radiation dose per procedure (mGy)</td>
<td>738 (24–3,085)</td>
<td>43 (2–829)</td>
</tr>
<tr>
<td>Aspiration</td>
<td>552 (83–1,377)</td>
<td>34 (5–286)</td>
</tr>
<tr>
<td>Biopsy</td>
<td>772 (24–3,085)</td>
<td>41 (2–829)</td>
</tr>
<tr>
<td>Catheter drainage</td>
<td>936 (221–1,653)</td>
<td>52 (7–268)</td>
</tr>
<tr>
<td>Procedure time (min)</td>
<td>25 (3–125)</td>
<td>17 (4–65)</td>
</tr>
<tr>
<td>Aspiration</td>
<td>18 (3–55)</td>
<td>15 (5–45)</td>
</tr>
<tr>
<td>Biopsy</td>
<td>30 (8–125)</td>
<td>17 (4–65)</td>
</tr>
<tr>
<td>Catheter drainage</td>
<td>25 (20–45)</td>
<td>20 (10–45)</td>
</tr>
</tbody>
</table>

The intermittent-only mode of CT fluoroscopy image acquisition was used in 196 (97%) of the 203 cases. With this operational mode, all personnel dosimetric results were below 0.1 mGy. A combination of the continuous and intermittent modes of image acquisition was used in seven cases (3%). In these cases, the median total procedure time was 14.2 minutes (range, 7–20 minutes), median total CT fluoroscopy time was 20.7 seconds (range, 6.6–36.0 seconds), and median maximum calculated patient absorbed dose per procedure was 71.4 mGy (range, 13.0–141.7 mGy). In one of these cases, a radiologist’s ring badge had a measurable reading of 1 mGy (continuous mode was used 90% of the time with 120 kVp, 40 mA, a section width of 5 mm, and a total CT fluoroscopy exposure time of 9.8 seconds). The remaining six cases (for which a combination of the continuous and intermittent modes was used) had occupational exposure readings less than 0.1 mGy.

The median procedure time was 32% less with CT fluoroscopy. Overall median procedure time was 17 minutes per procedure with CT fluoroscopy, compared with a median of 25 minutes for conventional CT ($P < .05$) (Fig 2, Table).
Total CT fluoroscopy times varied slightly among procedure types, with a median of 7.5 seconds for aspirations (range, 1.2–69.0 seconds), 11.3 seconds for biopsies (range, 1.2–187.6 seconds), and 13.8 seconds for catheter drainages (range, 1.6–64.8 seconds). Total CT fluoroscopy time was significantly less for aspiration procedures ($P < .05$) than for biopsy or drainage procedures. No significant difference in the amount of CT fluoroscopy time was noted between biopsy and drainage procedures.

A standard 120 kVp was used in every case. For conventional CT, current values ranged from 240 to 280 mA. For CT fluoroscopy, current values varied between 10 and 50 mA, depending on the type or site of procedure and patient size. Typical current values were 10 mA for pediatric patients, 10–40 mA for chest cases, 40–50 mA for abdominal cases, and 30–50 mA for bone cases. These values allowed adequate image quality with visualization of the region of interest and needle tip in 201 (99%) of 203 cases. The two cases in which the region of interest was poorly visualized were a small solid liver lesion and a small fluid collection deep in the pelvis. A section collimation of 5–7 mm was used in nearly all cases; in some cases, section collimations of 3 and 10 mm were used.

Biopsy specimens were histologically proved to be diagnostic in 121 (83%) of the 146 CT fluoroscopy–guided biopsy procedures and 62 (90%) of the 69 conventional CT–guided biopsy procedures. This difference was not statistically significant. We did not use on-site evaluation of the biopsy specimen by a cytopathologist. At our institution, nondiagnostic biopsies are handled with either repeat biopsy performed on a subsequent day, pathologic confirmation by some other means (eg, surgical), or clinical and imaging follow-up if appropriate. The success rate of aspiration and drainage catheter procedures was 100% for both CT fluoroscopy and conventional CT.

Major complications occurred in two CT fluoroscopy–guided procedures. One patient developed a pseudoaneurysm of the inferior gluteal artery, which required coil embolization. In a second patient, a small mesenteric hemorrhage developed. This patient’s symptoms of pain and hypotension resolved after the intravenous administration of fluids. No major complications occurred during any of the conventional CT–guided procedures.

Procedure sites for conventional CT–guided procedures included the abdomen ($n = 32$), pelvis ($n = 26$), retroperitoneum ($n = 20$), chest ($n = 9$), bone ($n = 7$), and soft tissue ($n = 5$). Procedure sites for CT fluoroscopy–guided procedures included the abdomen ($n = 43$), pelvis ($n = 25$), retroperitoneum ($n = 48$), chest ($n = 53$), neck ($n = 2$), bone ($n = 17$), and soft tissue ($n = 15$). The increased number of chest procedures performed by using CT fluoroscopic guidance is because all of our outpatient lung nodule biopsies are performed at our larger hospital where our CT fluoroscopy unit is located.

Of the 203 CT fluoroscopy–guided procedures, 150 (74%) were performed by residents or fellows and 53 (26%) were performed by staff radiologists. Of the 99 conventional CT–guided procedures, 41 (41%) were performed by residents or fellows and 58 (59%) were performed by staff radiologists. Total procedure times and CT fluoroscopy exposure times were not significantly different among these three radiologist groups.
The results of our early experience with CT fluoroscopy for the guidance of interventional radiologic procedures show that it markedly decreased the maximum calculated radiation dose to the patient compared with that of conventional CT. Our findings are the result of various factors, the two most important being the decreased tube current and the use of the intermittent (quick-check) mode of image acquisition, which allowed for low total CT fluoroscopy times and a markedly decreased number of CT sections. The reduction in dose by a factor of approximately 17 is primarily the result of the reduction in tube current used (nearly seven times lower). The remaining dose savings is owing to the availability of efficient single-section acquisition with the CT fluoroscopy system compared with conventional CT-guided procedures in which cluster scanning is used.

CT fluoroscopy was specifically designed for use in interventional procedures because this mode is not intended to serve as a diagnostic scan, a lower current can be used, which helps decrease patient radiation dose. Images obtained in this manner have decreased spatial resolution (256 × 256 pixel matrix) and image quality; however, they allow sufficient visualization of the region of interest (needle tip and lesion) in the majority of cases (Figs 3, 4). In our study, the area of interest was adequately seen in 99% of the 203 cases. Our current values ranged from 10 to 50 mA, depending on patient size and the area of the body imaged. A further reduction in patient radiation dose could be obtained by using even lower current values when possible, particularly when lesions are large, fluid or cystic (good inherent contrast), superficial, or easily accessible. This encourages greater radiologist involvement in setting up the scan so the lowest current value is used.

It is difficult to directly compare patient radiation exposure results with those of other studies in the literature because of differences in CT fluoroscopy scanner vendors, CT imaging parameters (particularly current), total CT fluoroscopy times, and mode of image acquisition (intermittent versus continuous [real-time]). In one prospective study (7) comparing CT fluoroscopy with conventional CT, the investigators found no statistically significant difference in patient radiation dose and reported a mean patient dose per procedure of 6,724 mGy with use of CT fluoroscopy, although they also noted that no precise dosimetric measurements had been conducted and their findings were approximations only. The results of another study (8) comparing CT fluoroscopy with conventional CT support our findings of a decrease in patient dose with the intermittent mode. However, their reported mean patient dose of 300 mGy per procedure in which the intermittent mode was used differs considerably from our median calculated dose of 43 mGy. In both of these studies, the higher patient doses were likely due to a combination of increased current values that ranged from two to six times higher and total CT fluoroscopy times that ranged from three to 10 times higher than those in our study.

The results of our study demonstrated potentially high radiation exposure to patients undergoing conventional CT–guided procedures (our maximum calculated exposure was 3,085 mGy), particularly in difficult cases in which multiple sections were acquired. Dose reduction could be achieved with conventional CT guidance by reducing current and matrix size (reducing matrix size reduces noise variation). Theoretically, a dose reduction of as much as seven times (the ratio of typical diagnostic current to typical CT fluoroscopy current) could be achieved by using an otherwise conventional CT–guidance mode of operation. However, the time efficiency associated with the CT fluoroscopy–specific system would not be realized in such a scenario.

Our results also showed a statistically significant decrease in overall procedure time with CT fluoroscopy compared with conventional CT. Because we began our study during the 1st month of CT fluoroscopy use, we expect a further decrease in procedure time as radiologists gain familiarity with CT fluoroscopy. Our data showed no statistically significant difference in CT fluoroscopy exposure time or total procedure time between staff and nonstaff radiologists performing the procedures. Our radiologists found procedures to be performed more easily with CT fluoroscopy and preferred it to conventional CT in nearly all cases. The ability to rapidly obtain intermittent (quick-check) CT images for needle position was most beneficial in cases of small lesions and in cases in which there was limited access to the lesion (Fig 5). It was also helpful with critically ill or uncomfortable patients who had difficulty lying for an extended period prone.
conventional CT. Silverman et al (8) reported a statistically significant shorter needle placement time with CT fluoroscopy, but they believed that the overall time in the room was not considerably reduced. Although we have no supporting data (the total time in the room was not recorded in our study), we believe that the decrease in procedure time has led to a decrease in total time in the room per procedure. This is important for increased patient throughput and increased patient access to the scanner.

Although CT fluoroscopy can decrease procedure time, one major aspect of learning to use CT fluoroscopy in the intermittent mode of image acquisition is the ability to find the needle tip. With conventional CT guidance, radiologists typically obtain multiple CT images after each needle or catheter advancement, which increases the likelihood for identification of the characteristic needle tip artifact. With CT fluoroscopy, a single CT image is obtained, and if the needle tip is not within the plane of imaging, a decision has to be made to move the table some estimated distance and in some expected direction. This can increase procedure time and CT fluoroscopy time. Familiarity with this technique will likely solve this problem and lead to a further decrease in overall time. The ability to perform CT fluoroscopy with a multi–detector row CT scanner may also overcome this obstacle, because a cluster scan mode might be available that would allow initial localization of the needle tip from a single exposure (four CT sections per single rotation of the CT x-ray tube). Using a single–section mode on the multi–detector row scanner for subsequent acquisitions would still allow lower patient dose to be achieved relative to the dose with conventional CT guidance.

Because of the ability to operate in a continuous acquisition mode, CT fluoroscopy has a greater potential for radiation injury to the patient and substantial personnel exposure compared with conventional CT guidance. CT fluoroscopy can deliver a considerable radiation dose to the patient, up to 2 Gy/min with use of typical diagnostic parameters (120 kVp, 280 mA) or more typically 0.3 Gy/min with use of typical CT fluoroscopy parameters (120 kVp, 40 mA). Although the CT fluoroscopy dose rate is approximately seven times lower than that for diagnostic scanning, it is a factor of 10 higher than the dose rate delivered with conventional fluoroscopy (although longer exposure times are typically used with conventional fluoroscopy, and a larger area of tissue is irradiated compared with thinly collimated CT sections). Therefore, it is essential to use a minimal exposure time and the lowest current values that allow adequate image quality during the procedure.

With our current CT fluoroscopy system (GE HiSpeed CT/I CT scanner with SmartView), the technologist has the ability to increase the current value to diagnostic levels. The implementation of a software limit for the current value may be helpful in preventing radiation injury during procedures in which CT fluoroscopy is used. The Food and Drug Administration has suggested that manufacturers develop radiation dose rate displays visible to the operators of CT fluoroscopy (5).

The potential for considerable radiation dose to the operator’s hands during the CT fluoroscopy continuous mode of acquisition makes a needle–holder device essential to keep the hands out of the direct primary beam during needle placement and advancement (10). At our institution, a 6-inch or 10-inch sterile stainless steel forceps is available as a needle–holder device. However, owing to decreased tactile feedback and difficulty with needle advancement through resistant tissue planes, all of our current radiologists prefer incremental (0.5 mm) needle placement, with intermittent fluoroscopy for quick checks of needle and catheter positions. This conflict conflicts with that from Kato et al (10) that needle placement was just as easy and fluoroscopy times were not increased by using real–time (continuous mode) CT fluoroscopy and a needle–holder device. We have limited data on continuous mode CT fluoroscopy; however, in the few cases in which the continuous mode was used, increases in CT fluoroscopy time and median patient radiation dose per procedure were noted.

The major limitation of our study is that we performed few procedures with the continuous (real–time) acquisition mode of CT fluoroscopy. As the radiologists at our institution become more familiar with this new modality and as improved needle–holder devices are developed, real–time CT fluoroscopy may be used with an increased frequency in select situations. The development of 0.5-mm lead equivalent gloves that are flexible enough to adequately manipulate the small interventional tools we use may also help. However, given the increases in CT fluoroscopy time and patient and personnel radiation doses reported in the literature (7–9), our limited experience in the few cases in which continuous mode CT fluoroscopy was used, and the fact that use of the intermittent mode allows for significantly decreased procedure times with little radiation exposure, we advocate use of the intermittent mode of CT fluoroscopy image acquisition whenever possible and recommend reserving use of the continuous mode in select cases only (ie, cases in which respiratory motion is a problem). Whereas others have focused on CT fluoroscopy’s capability of real–time imaging, we have focused on its capability of fast acquisition of a single CT section to decrease procedure time.

In conclusion, although CT fluoroscopy has the potential to deliver high radiation doses, using the lowest current that will still give high–quality images and taking advantage of the intermittent mode of image acquisition decreased patient and operator exposure substantially. As implemented at our institution, CT fluoroscopic guidance markedly decreased patient radiation dose, significantly reduced total procedure time, and maintained acceptable occupational exposure levels.

References