Clinical Imaging 40 (2016) 431–434

Contents lists available at ScienceDirect

Clinical Imaging

journal homepage: http://www.clinicalimaging.org

Review Article

CT versus ultrasound guidance for percutaneous drainages in the pediatric population: an institutional review meant to limit radiation

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ARTICLE INFO

Article history:
Received 14 July 2015
Received in revised form 22 November 2015
Accepted 15 December 2015

Keywords:
Drainage
Utilization
Radiation reduction
Ultrasound

ABSTRACT

Computed tomography (CT)-guided percutaneous drainage is a minimally invasive procedure that allows for accurate diagnosis and therapy with minimal complications. The drawback is that CT guidance carries a significant amount of radiation exposure. CT-guided percutaneous drainages have been widely used in adults and have been gaining momentum within the pediatric population. Through a thorough review of our institution's (Montefiore Medical Center) CT-guided percutaneous drainages within our pediatric patients, we assessed the radiation exposure per study as well as which studies were deemed possible under ultrasound guidance as a possible alternative.

1. Introduction

Catheter drainage with computed tomography (CT) guidance has become a therapeutic mainstay for treatment of intraabdominal abscesses [1]. While CT-guided catheter drainage may require sedation, it avoids some of the more serious complications associated with open surgical drainage including cross-contamination within the peritoneal cavity, incision site infection/dehiscence, and adhesion formation [2]. Furthermore, percutaneous CT-guided drainage has been shown to reduce the length of hospitalization [3]. Predrainage CT imaging allows for delineation of the abscess cavity and provides a roadmap to avoid injury to adjacent viscera or blood vessels. CT-guided percutaneous drainages have been widely used in the adult population. Given positive outcomes, the technique has been adopted for use in the pediatric population [4–7]. However, ionizing radiation of CT-guided drainage is cumulative to the radiation used for initial scan and surveillance [8].

Long-term studies have shown that ionizing radiation in childhood carries a significantly increased lifetime risk of developing fatal cancer [9–11]. ALARA ("as low as reasonably achievable") describes the role of the radiologist in reducing radiation exposure without compromising diagnostic efficacy [12]. Some measures that have already been implemented include development of weight-based protocols, increased consideration of alternative imaging modalities such as ultrasound (US) and magnetic resonance imaging (MRI), improved shielding techniques, focused and/or limited-view studies when clinically appropriate, and decreasing the number of CT studies [12].

While there have been studies examining radiation exposure to staff and patients during CT-guided percutaneous abscess drainage [12,13], none has focused on a pediatric patient population. The purpose of this study was to examine and quantify the radiation dose children are exposed to during CT-guided percutaneous catheter drainage. Additionally, we will review our institutional experience and determine which procedures were amenable to US-guided drainage thereby obviating the radiation exposure.

2. Materials and methods

2.1. Subjects

This study approved by institutional review board and compliant to Health Insurance Portability and Accountability Act was a retrospective review assessing radiation exposure during CT-guided abscess drainage in pediatric patients. The radiology information system was searched for pediatric patients who underwent CT-guided abscess drainage procedures. A total of 38 patients under the age of 21 years had 41 CT-guided abscess drainages performed from January 1, 2006 through September 18, 2013. The age range of participants that fit these criteria was from birth to 20 years with the average age of 12.8 years.

2.2. CT dose measurement

Four different CT units, indicated in Table 1, were used for drainage procedures during this time. Effective dose was calculated for each procedure using the DLP (dose–length product) per examination and

Conflict of interest: The authors confirm that this article content has no conflicts of interest.

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http://dx.doi.org/10.1016/j.clinimag.2015.12.004
0899-7071/

Table 1
CT units used in this study

Manufacturer	Model	Maximum rows
General Electric	LightSpeed RT 16	16
	LightSpeed VCT	64
	HiSpeed CTi	1
Philips	Brilliance 16	16
Philips	Mx 8000 IDT	16

published conversion factors [14]. Since only one of the CT units utilized provided a dose report with the $CTDI_{vol}$ and DLP at the end of the examination (the GE LightSpeed RT 16), these dose quantities were estimated for the other three units. The $CTDI_{vol}$ is a measure of the radiation output of the CT scanner but can be used to estimate an average dose in the irradiated volume of tissue and the maximum skin dose [15].

The effective doses, once derived, reflect the risk of harmful biological effects from a partial-body exposure in terms of a whole-body exposure and can be used to compare the relative risk from different imaging procedures and scanners that use ionizing radiation [16]. The mAs and $CTDI_{vol}$ used to calculate the effective dose were *averages* for their cumulative series based on values given in PACS. The DLP and effective dose in the table are not averages but rather the total radiation and total effective dose for each patient.

For the Philips Brilliance 16, $CTDI_{vol}$ was displayed by the unit for each slice in each series. The DLP was estimated by multiplying the average value of $CTDI_{vol}$ for all slices by the number of axial slices and the corresponding slice thickness. An adjustment to the DLP calculation was included for overranging that occurs during helical scans [17,18]. The other two older CT units did not provide a value of $CTDI_{vol}$. Therefore, data contained in the annual quality control test reports for these units, the Philips Mx 8000 IDT and GE HiSpeed CTi, were used to generate tables of the normalized weighted CTDI, $CTDI_w$ (mGy/mAs) for different collimation settings.

The $CTDI_{vol}$ was then computed with Eq. (1),

$$CTDI_{vol} = CTDI_w(\mathrm{mGy/mAs}) \times (\mathrm{mAs}) \times (1/\mathrm{pitch}) \qquad (.\ 1)$$

The DLP was then converted to effective dose in millisieverts (mSv), using published conversion factors that vary with the patient's age and specific body region scanned (Table 2) [19], using Eq. (2). There have been several recent publications [16,20,21] that have reevaluated the k factors but we have elected to use the original values until a consensus is established regarding the revised figures

$$\text{effective dose}(\mathrm{mSv}) = k \times DLP \qquad (.\ 2)$$

Each patient's drainage procedure indication was retrieved from the radiology drainage report (Table 3).

2.3. Procedure review

All CT drainage images were anonymized and retrospectively reviewed by two separate pediatric radiologists; one with 15 years of pediatric radiology experience (BT) and one (AM) with 6 years of radiology training. The image sets were reviewed independently to determine whether US could have been used for drainage (Fig. 1). Both radiologists had been trained in CT-guided drainages as residents but had not performed drainages after residency. Criteria included the increased subcutaneous tissue obscuring visualization of the abscess and interposed bowel loops between the skin and abscess cavity (Fig. 2). Each reader graded in a binary system whether or not drainage was possible. Results were recorded in an excel format. Any disagreement in grading was resolved in combined panel review of participating radiologists.

Table 2
k Factors and effective dose per DLP

Region of body	k, effective dose per DLP [mSv/(mGy-cm)] by age				
	0	1 year	5 years	10 years	Adult
Head and neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen and pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

3. Results

Of the 38 patients who had CT-guided abscess drainages, 18 were male and 20 were female. The study population had an average age of 12.8 years (range 3–20). Of the 38 patients, 3 had a second CT-guided abscess drainage within 8 days (Patients 6, 7, and 23 in Table 3). Patient 16 had two different kVp values within one study (Table 3). One patient had no retrievable images for this procedure so radiation exposure could not be reported.

The age, gender, indication for drainage, area scanned, $CTDI_{vol}$, DLP, effective dose, and possibility of US guidance are shown in Table 3 for each patient in the study. The average effective dose for this study was 5.74 mSv (range 0.58–39.35 mSv) (chart 1, Table 3). Of the 38 patients, 12 had effective dose values that were above the average. The average DLP was 378.44 mGy-cm (range 38.93–2623.22 mGy-cm) (chart 2). Of the 38 patients, 12 had DLP values above the average. A total of 24 scans in 22 patients were due to complications of appendicitis, whether due to perforation or fluid collections after surgery. The average DLP for appendicitis was 395.31 mGy-cm (range 38.93–2623.22 mGy-cm).

Of the 38 CT-guided drainages, 28 cases were deemed amenable to US-guided drainage. Of the 13 cases where US could not be used, the most common reason was bowel surrounding the lesion. In 5 cases, the patient's body habitus precluded use of US. One case required a posterior approach crossing the pelvic musculature.

Of the 28 drainages that could in retrospect have been performed with US, the average DLP was 378.44 (mGy-cm) (range 38.93–2623.22 mGy-cm). The effective dose average was 5.74 mSv with a range of 0.58–39.35 mSv.

4. Discussion

US has been advocated as an alternative to CT for percutaneous abscess drainage [1] but has not been extensively evaluated for feasibility in children. While CT provides better anatomic information, US permits real-time observation of the abscess and the catheter, without ionizing radiation exposure. If US depicts only part of an abscess, US can be supplemented with fluoroscopy for better planning, guide-wire deployment, and drain positioning [1]. Another technique that may also assist in reducing radiation dose would be to replace predrainage CT scans in patients with complicated abscesses with an MRI to help better understand the underlying anatomy prior to drainage with US. In cases that in retrospect were amenable to US, the average radiation reduction that could have been achieved was 5.32 (mSv).

Current literature is partial to CT-guided drainages over other modalities yet it does acknowledge the importance of reducing radiation exposure in the pediatric population by utilizing safer methods such as US, especially in the cases of children [21]. As demonstrated by the review of images in our study, many of these abscess drainages could have been performed using US guidance as opposed to CT. This paper is not meant to completely discount CT as a useful modality in drainage procedures. CT is advantageous for targeting collections not visible with US as well as providing a more complete anatomic layout of the field and nearby critical structures. CT has its place where better understanding of the full extent of the abscess size and location is required [22]. Operator experience with CT imaging can drive individual preferences.