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COMMENTARY

'Here's looking at you, kid' … again? Revisiting multiphase CT in children

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This is about multiphase CT and *Casablanca*, the movie. Stay with me to explore this connection (and what better splicing for radiology than with film). *Casablanca* was an Academy Award winning movie starring Humphrey Bogart and Ingrid Bergman set in late 1941 in Morocco in Northern Africa. Often listed as one of the top five movies of all time, it is an epic story of love and resistance set in wartime, and in the end it is about making tough decisions in a background of changing times that are at odds with the ease of doing the same old thing … and a friendship forged on a foggy runway.

The landscape

And when CT examinations are performed in kids, we seem to continue to do the same old thing: multiphase scanning. This was highlighted in a recent article in *Pediatric Radiology* by Rostad et al. [1]. Investigators compared abdominopelvic CT examinations performed at outside imaging facilities with those obtained at their practice (population of 939 abdominopelvic CTs) at a large children's hospital, for patients up to early 20s in age. Of 754 contrast-enhanced abdominopelvic CTs from outside imaging facilities, 55% had more than one phase, including 2% with three phases. This contrasted with the investigators' institution, where multiphase examinations comprised 12% of the total number CT examinations. Guite et al. [2] reported on a total of 500 abdominopelvic CT examinations, consisting of 978 phases in individuals from 9 months to 90 years of age, and assessed whether additional phases were justified according to the American College of Radiology (ACR) Appropriateness Criteria. Investigators found that 35.8% of phases were unindicated. One of the center-stage consequences to "unindicated" is additional radiation exposure. In the Guite investigation, the mean effective dose for the unindicated phase was 13.1 milliSieverts (mSv), with 33.3% of total examination radiation dose to the study group resulting from unindicated phases [2]. Kim et al. [3] reported on data available from 344 children imaged at outside imaging facilities in the setting of acute abdominal pain/possible appendicitis and found that 40% were imaged with suboptimal technique (e.g., wrong phase or multiphase examinations), with multiphase examinations accounting for 17% (60 of 344); 2% were triple-phase CT examinations [3]. Of note, the estimated organ doses for the single-phase examinations between the researchers' institution and those from the outside imaging facilities were not significantly different, implying that headway is being made with dose reduction efforts for individual phases but not for the total number of phases. Radiation savings are diluted, though, when additional phases add to the cumulative radiation examination for the entire study. Smith-Bindman et al. [4] documented radiation dose metrics at five University of California programs from consecutive CT examinations across all ages, including 3,871 examinations in 2,609 children younger than 14 years. In this group, 18% of chest, 12% of abdomen, and 42% of chest and abdomen CT examinations were multiphase. The issue of unnecessary scans ("double scans") was also reported in the Medicare population [5]. Finally, the actual numbers of multiphase scans may be underreported even given these numbers. Wildman-Tobriner et al. [6] in a survey of pediatric CT scans from the ACR Dose Index Registry found that 32.4% of single-phase-labeled exams consisted of multiple irradiation events (discounting the localizer).

The correct lens?

What lens should we be looking through? The answer is one that is more focused than the current multiphase practice in up

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to 55% of pediatric CT abdominopelvic examinations. Cooper et al. [7] looked at 2,390 abdominopelvic CT scans in children younger than 16 years at a children's hospital: 1.4% were multiphase, with 1% more repeated because of movement. Goske et al. [8] performed a multicenter study consisting of six institutions with pediatric focus (children's hospitals or university-based teaching hospitals that include pediatric care). The investigation consisted of 954 abdominopelvic examinations in children younger than 18 years who were evaluated for a broad spectrum of conditions consisting of abdominal pain, inflammation or mass: 2% were multiphase CT examinations (14 dual-phase and 1 triple-phase). Snow and colleagues [9] compared 50 abdominopelvic CT scans from outside imaging facilities with their studies at a children's hospital and found that in both populations unnecessary phases were limited to 2% of studies.

Bad actors

While the potential risk from CT radiation is at most still small with additional phases, it is very difficult to defend exposing anyone, let alone children, to unnecessary radiation from non-contributory series. However, reviewing the multiphase examination film roll, there are some additional scratches. Multiphase examinations take longer to perform, reducing efficiency in use of the CT scanning suite. Multiphase protocols have to be created and monitored (e.g., audited) and the more complex this process is, the greater the effort for these requisite activities. It can be difficult, as well, when considering radiation doses for multiple series to account for a cumulative representation of radiation exposure, especially if volumetric CT dose index ($CTDI_{vol}$) and size-specific dose estimates (SSDE) are used because these are not additive. Recording these metrics in patient reports engenders additional information that may only conflate a poorly understood component of the radiology report for the referrer as well as the patient or caregiver. More images are generated that need to be reviewed, contributing to the workload, and potentially fatigue, for the radiologist as well as the technologist. Data entry for CT registries may be challenged by an increased number of series. For children with limited compliance, prolonged overall scan duration increases the chance of motion artifact. Additional and sometimes large table translation on some scanners may adversely affect patients with a support apparatus. Additional phases certainly do not prolong the life of the CT scanner. It is not uncommon for additional phases to be performed with the same parameters, resulting in a multiplication factor that is the number of additional phases. The benefits in radiation exposure reduction from other techniques, such as kilovoltage (kV) reduction or modulation, iterative reconstruction, avoidance of overlapping regions with multi-region scanning, and tube current reduction (especially through modulation), are worthy efforts but are reduced or eliminated with additional *unnecessary* phases of scanning. Simply stated, subscribing to multiphase scanning without reviewing its necessity is not best practice in pediatric CT. Now let's go back to *Casablanca* (and a central song, "As Time Goes By"), with one minor adjustment — a note to incomplete radiation dose reduction:

> "You must remember this
> A *miss* is still a *miss*, a sigh is just a sigh
> The fundamental things [still] apply
> As time goes by"

Setting the stage

"Welcome back to the fight. This time I know our side will win." (Victor Laszlo to Humphrey Bogart's character Rick Blaine in support of the cause). We know the cause — subscribing to a reasonable percentage of multiphase scanning in children — so what is the script to follow? First, multiphase scanning does have a place, it simply needs to be justified. Indications can be found in the ACR Appropriateness Criteria and can include evaluation of potentially cystic lesions, evaluation that requires arterial and venous vascular enhancement (e.g., liver transplantation), or in the trauma arena to assess for bleeding from vasculature or solid organs as well as disruption of the renal collecting system. There is no published number to my knowledge for each of the indications for the spectrum of pediatric abdominopelvic or chest examinations that should routinely be multiphase, but this should probably be no more than 5% of the total as a target, with a substantive review of practice when this number is, for example, greater than 10%.

There are other strategies to obtain multiphase information, such as dual-phase imaging during one acquisition that would give, for example, arterial and venous phase information, using a split bolus technique. Dual-energy CT can also provide information that was previously only possible with different phases of acquisition during IV contrast media administration. When multiple phases are warranted, parameters should be adjusted so that the requisite information can be obtained with the minimal radiation exposure, which includes scanning only the necessary range. These strategies are not new, and the observation that multiphase scanning remains a cause of unnecessary radiation exposure in children is troubling. Education is an important component; justifying multiphase CT scanning in children has been a longstanding pillar of the Image Gently Alliance. Blumfield et al. [10] studied a

sample of head and abdominal CT examinations over the period 2005–2010 at two hospitals with varied levels of pediatric expertise. The authors showed that a change in practice from several interventions during that period resulted in a decrease from 35 additional phases in a sample of 50 abdominopelvic CTs in 2005 (1.7 average abdominal phases/scan) to 2 additional phases in 2010 (1.04 average phases/scan) [10]. Educational efforts can include notification of practices where multiphase scanning is relatively prevalent [1]. These efforts require resources, diplomacy and measured outcomes through follow-up initiatives.

Paterson et al. [11] in discussing the lack of adjustments for CT scanning in children in 2001 noted that 31% of the children whose chest and abdominopelvic CT examinations were reviewed underwent multiphase examinations. Seventeen years later we "Play it again, [Sam]." And for the record, when Ilsa (Bergman) enters Rick's Café Américain in *Casablanca*, she actually says "Play it once, Sam, for old times' sake," not the misquoted "Play it again, Sam." So let's just try to *play it once*, and minimize the unnecessary performance of multiphase CT imaging in children. Make tough, but informed, decisions that are at odds with the ease of doing the same old thing.

About the fog and friendship? At the end of *Casablanca*, on the runway, the plane takes off carrying Ilsa and Laszlo up and out of the fog and to a hopeful future. And Bogart walks with the local military captain, sympathetic to the cause, and remarks, "I think this is the beginning of a beautiful friendship."

Compliance with ethical standards

Conflicts of interest None

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