Single Center Experience With Application of the ALARA Concept to Serial Imaging Studies After Blunt Renal Trauma in Children—Is Ultrasound Enough?

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Abbreviations and Acronyms

CT = computerized tomography

PBRT = pediatric blunt renal trauma

US = ultrasound

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Purpose: After properly staged renal injury many children will undergo radiological reevaluation with computerized tomography, the modality frequently favored for its widespread availability and anatomical detail. The ALARA (as low as reasonably achievable) concept attempts to balance the potential future risk of radiation induced malignancy with the added information obtained by the study. At our institution ultrasound has been increasingly adopted as the followup imaging technique of choice. We sought to evaluate this practice in pediatric blunt renal trauma management.

Materials and Methods: We retrospectively analyzed the trauma database of a pediatric referral center for patients treated between 1997 and 2007. A total of 73 children with blunt renal trauma were identified. Associated injuries, mechanism of trauma, type of management, imaging studies, complications and delayed/missed injuries were evaluated.

Results: Mean patient age was 10.5 years and the male-to-female ratio was 3:2. In all patients the mechanism was blunt trauma. Average grade of injury at hospitalization was 2.4, with high grade injury observed in 32% of patients. Repeat computerized tomography was obtained in 11 patients (9 for nonurological injuries). Three nephrectomies were done in the setting of hemodynamic instability and 1 pseudoaneurysm was embolized. Four enlarging symptomatic urinomas were suspected by ultrasound. No clinically important injuries or complications due to delayed diagnosis were detected in patients followed with ultrasound.

Conclusions: Our experience suggests that after initial computerized tomography for accurate staging of pediatric blunt renal trauma monitoring can be performed with ultrasound in most patients (excluding those with hemodynamic instability or deemed to require computerized tomography for associated injuries). Selective reevaluation with computerized tomography can be reserved for those with serial or ambiguous abnormalities detected on ultrasound, thus decreasing exposure to radiation.

Key Words: pediatrics; radiation dosage; tomography, emission-computed; ultrasonography; wounds and injuries

Trauma is an important cause of morbidity and mortality in children. In particular, renal trauma can be associated with life threatening complications and long-term consequences. With advances in diagnosis and management a largely successful shift toward close monitoring and nonoperative/minimally inva-

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sive treatment has occurred. Widely available modern imaging techniques are partly responsible for this phenomenon.

CT is the imaging modality of choice for early accurate identification and staging of internal organ injuries.[1] In fact, its use in adults and children has increased tremendously in recent years.[2,3] Although CT is versatile and provides excellent anatomical delineation, the need for ionizing radiation remains one of its main drawbacks. Most worrisome is the potential association between low dose radiation exposure in childhood and the future small, albeit noteworthy, increase in malignancy risk.[2–6] Thus, efforts aimed at decreasing this exposure through technological improvements and adoption of alternative imaging techniques have been favored, particularly in children. The ALARA principle has been articulated to reduce radiation exposure in pediatric patients,[7] given their longer life expectancy, increased radiation sensitivity and additive risk with repeated exposure. Current best practices for followup imaging after renal trauma have not been standardized, appear to reflect expert opinion rather than evidence and do not directly address the issue of radiation exposure. Similarly, published data provide limited guidance as to the usefulness of followup imaging studies in terms of changing management or providing valuable additional information.

To our knowledge the ALARA concept has not been systematically applied to pediatric post-renal trauma monitoring. At our institution the tradeoff between added diagnostic information, and risk of radiation and intravenous contrast administration has been addressed by a progressive shift toward US as the followup imaging technique of choice (with selective CT reevaluation). We analyzed data from our trauma database to evaluate the value of this practice in the management of PBRT.

MATERIALS AND METHODS

After obtaining institutional review board approval we retrospectively analyzed information for patients with blunt renal injury treated between 1997 and 2007 from the prospectively collected trauma database of a single freestanding pediatric hospital. A total of 73 children with PBRT were identified through the registry and their records were reviewed. The American Association for the Surgery of Trauma injury scale was used to grade renal injury,[8] based on the first CT performed after the injury and confirmed by an independent radiologist. High grade renal injury was defined as grade 4 or 5. Two patients without a properly performed trauma CT at presentation were subsequently excluded from study.

Patients were either referred from elsewhere or transported directly to our hospital for treatment. Consequently, initial management was not homogeneous. Children with evidence of genitourinary injuries were evaluated by a pediatric urologist in conjunction with the trauma team. Patients who were hemodynamically unstable underwent surgical exploration. In selected cases children with a sequential decrease in hemoglobin despite blood transfusions were considered for angiogram and embolization. All remaining children were initially treated following a nonoperative (conservative) protocol, which included bed rest, close hemodynamic monitoring, serial laboratory evaluations (hemoglobin, electrolytes, creatinine) and US with Doppler evaluation (at approximately 48 hours, or sooner if a worrisome change in clinical status developed). Thus, stable patients with persistent hematuria, progressive decrease in hematocrit, fever or worsening abdominal pain were considered for ultrasound evaluation followed by selective CT if US was inconclusive.

Associated injuries, mechanism of trauma, type of management (initially and during hospitalization), imaging studies obtained during hospital stay and followup visit(s), complications, and delayed/missed injuries were recorded and analyzed. Complications included persistent fever (greater than 101F), fluid collection/urinoma and bleeding/hematoma. Followup imaging was usually requested after pediatric urology consultation, with US being the technique of choice applying the ALARA principle. Hemodynamically stable patients with a normal sonographic evaluation or resolving abnormalities on US did not undergo repeat CT unless required for treatment of associated injuries or due to a change in clinical status. The timing and selection of imaging studies during followup evaluation(s) after discharge from the hospital varied at the discretion of the attending urologist, and was limited by patient and family compliance with outpatient monitoring recommendations.

RESULTS

Average patient age was 10.5 years and the male-to-female ratio was 3:2. Average grade of renal injury was 2.4, with 22 of 71 patients (31%) demonstrating high grade renal injury. The distribution of renal injury by grade is shown in the table. In all cases the mechanism of injury was blunt trauma. Hematuria was detected in 61 patients (86%), with gross hematuria documented in 46%. Associated injuries occurred in 49 patients (67%), with spleen and/or liver lacerations being the most common. Thus, isolated renal injuries occurred in 24 patients (33%).

Overall 3 nephrectomies were done for high grade PBRT in the setting of hemodynamic instability. In

Distribution of renal injuries in 71 patients with available initial CT

Injury Grade	No. Pts (%)
1	25 (35)
2	15 (21)
3	9 (13)
4	19 (27)
5	3 (4)

all cases attempts at renal salvage were unsuccessful. Four enlarging perinephric fluid collections were detected by US and managed by placement of a ureteral stent or percutaneous drain. One pseudoaneurysm with delayed bleeding was detected by ultrasound and repeat CT, and was treated with selective embolization. Repeat CT was ordered in 11 patients (15%). However, only 2 of these children underwent repeat scanning for urological reasons, 1 before embolization of the aforementioned pseudoaneurysm and 1 for an enlarging perinephric fluid collection. The remaining 9 patients underwent repeat CT for nonurological reasons (fig. 1).

Of patients with high grade renal injury surveillance was conducted by US in 17 and surgical exploration was performed in 2 (fig. 2). Of those followed with US no missed injuries or complications due to delayed diagnosis were detected.

Complications occurred in 16 patients (23%), 10 with high grade and 6 with low grade renal injury. Interventions were carried out in 6 of these patients (60%) with high grade renal injury, including 2 retrograde pyelograms with ureteral stent placement, 1 retrograde pyelogram with ureteral stent placement followed by nephrectomy for delayed bleeding, 2 nephrectomies for hemodynamic instability and placement of 1 percutaneous nephrostomy tube. Within the low grade renal injury group only 1 patient (17%) with a grade 3 injury required intervention (renal embolization for pseudoaneurysm) for persistent bleeding (fig. 3).

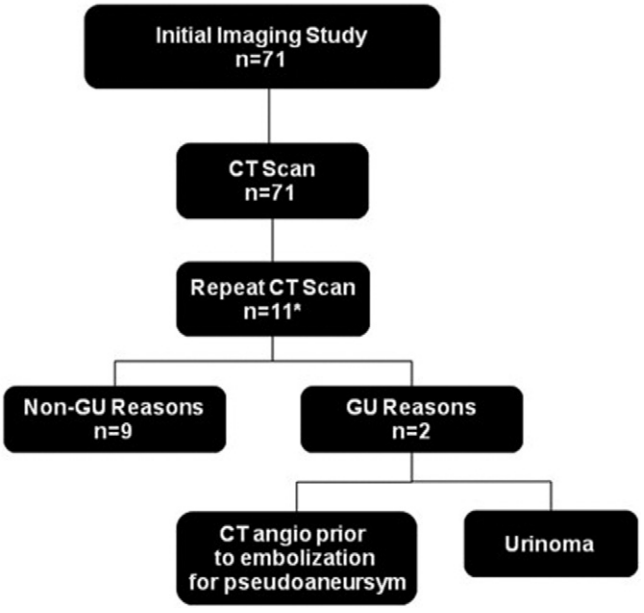

Figure 1. Flow diagram outlines initial and followup imaging modalities used in present series. *GU,* genitourinary. *angio,* angiogram. Asterisk indicates patients followed with repeat CT. Remaining patients were followed with US.

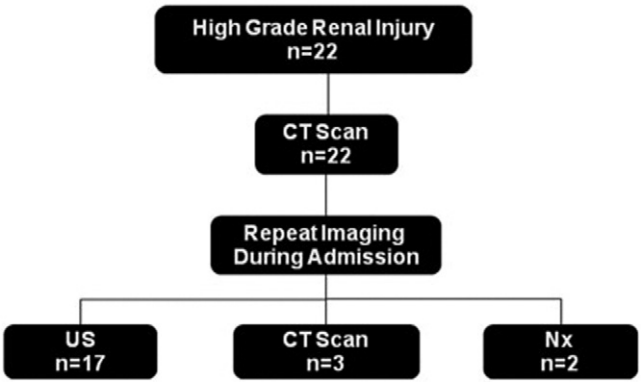

Figure 2. Flow diagram illustrates initial and repeat imaging modalities used in children with high grade (4 or 5) renal injury. *Nx,* nephrectomy.

Followup visits were recorded for 59 patients (83%), with an average followup of 10.8 months. Hypertension, defined as blood pressure greater than the 95th percentile for age and height, developed in 5 children (7%), including 3 following high grade renal injuries. Followup US was abnormal in all 5 patients (defined as perfusion abnormality by Doppler and/or renal parenchymal defect). Dimercapto-succinic acid scans were performed in 4 of these patients, and were abnormal in all 4 (decrease in differential function and/or renal parenchymal defect).

Among the 41 patients with grades 1 and 2 renal injuries complications (only persistent unexplained fever) occurred in 5, with none requiring urological intervention. Of these patients 35 underwent US during their hospital stay and 6 underwent no further abdominopelvic imaging. No clinically important missed renal complications were detected. None of these children underwent repeat CT for urological reasons.

DISCUSSION

To our knowledge this is the first study to evaluate the ALARA concept by using US in the acute surveillance of pediatric patients after blunt renal trauma. This principle has been widely supported in routine imaging of pediatric patients,[7] and has been considered in the treatment of particular problems such as vesicoureteral reflux.[9] In an attempt to reduce the risk of future malignancy the basic premise is to limit the use of ionizing radiation in children, since this population appears to be more radiosensitive and to have a greater lifetime risk of exposure.[6]

The liberal use of CT for evaluation and monitoring of pediatric trauma cases has been called into question, particularly for abdominal studies.[10] Although the initial CT is undoubtedly the preferred imaging technique for identifying and accurately

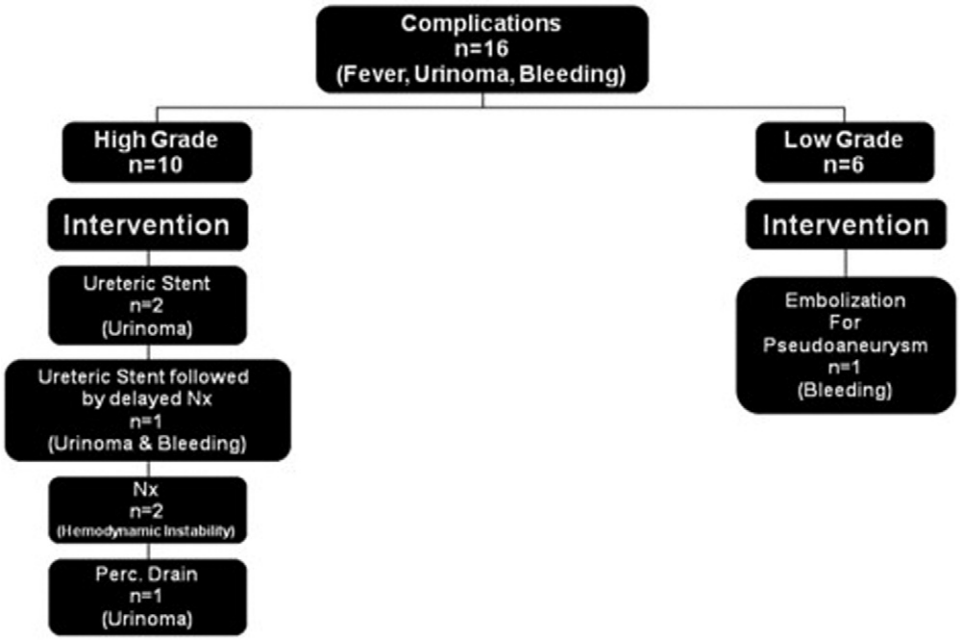

Figure 3. Flow diagram outlines complications encountered and interventions performed in present series. *Nx,* nephrectomy. *Perc.,* percutaneous.

staging renal injuries, the practice of repeat CT is worrisome because it leads to rapid accumulation of radiation doses. Furthermore, it appears that children are subjected to abdominal CT after trauma more frequently than adults, and that for those with low injury severity scores there is little if any treatment benefit.[11]

This topic has not been directly addressed in the setting of renal trauma in children. CT has been considered an important imaging modality for acute surveillance,[12] particularly in the monitoring of high grade renal injures.[13] In an effort to evaluate the child fully at presentation the initial study in most children who suffer abdominal and/or pelvic trauma is CT with intravenous contrast enhancement, usually ordered by the trauma team or the emergency room physician. This was the case in the present series. However, repeat CT was ordered for urological reasons in only 2 patients.

In this study surveillance US with Doppler typically was performed within 36 to 48 hours following renal injury in an attempt to detect an enlarging urinoma or hematoma, and to estimate perfusion to the renal parenchyma. Using this approach, we were able to evaluate 74% of patients with high grade renal injury with US, and encountered no clinically important missed injuries or complications. In particular, our nephrectomy rate for the entire cohort was 4%, which is similar to other studies.[14] Similarly, our renal salvage rate for conservatively treated patients was 96%, which is consistent with reports in previous series.[15] Furthermore, US allowed detection of enlarging fluid collections in 4 children with urinomas and subsequent placement of either a ureteral stent or percutaneous nephrostomy tube/drain. US was also used for detection of a pseudoaneurysm (a rare complication following blunt renal trauma).[16] Also, the majority of patients with grades 1 and 2 renal injuries were treated solely with US or clinical surveillance, and none required intervention.

Similar to the experience of others, conservative management was successful in our series. It is noteworthy that low grade injuries are likely to resolve in most children without intervention and, therefore, this group might receive no benefit whatsoever from followup imaging. Although our data support this concept, further studies are needed that are specifically designed to evaluate this issue in terms of adequate patient selection.

Hypertension occurred in 7% of our patients. On review of the followup imaging these patients had expected posttraumatic abnormalities detected on US and/or renal scan. Although the total number of patients at long-term risk for hypertension is unknown, it is a complication that needs to be monitored during surveillance. Unfortunately, better definition of the post-renal trauma consequences can be quite challenging, as this group tends to lack compliance with followup visits. Based on our findings, it seems prudent to monitor blood pressure after renal injury and to consider imaging in those found to be hypertensive.

None of the 3 patients who underwent surgical exploration were able to have the kidney reconstructed and salvaged. It is unclear if more liberal

use of CT would have changed the outcome for these patients, since the timing of events led to emergent surgical exploration without the opportunity to consider other options such as embolization. Nevertheless, this is an important concern, as the point along the risk-benefit spectrum where it is better to repeat CT over US is not well-defined. Therefore, individual decision making is still paramount. CT imaging should be favored in situations when a rapid, precise answer is needed, when ultrasound findings are inconclusive, when there is concern about changes in clinical status related to associated injuries not well evaluated by US, when intervention or management based on US results fails to translate into clinical improvement, or for cases with persistent/worsening hematuria, fever, pain, abdominal distention or ileus.

In the face of potential, long-term, serious consequences (although likely rare) the current tendency is to reduce radiation exposure whenever possible. Replacement of followup CT with US is likely to decrease the doses. However, it is unclear if there is an added risk to the patient. Other potential benefits, such as avoiding repeat administration of intravenous contrast material and possible lower costs, should also be considered. By not doing CT scans and US regularly in our series, it is also unclear if the latter failed to detect injuries that resolved without apparent clinical consequences or if CT would have prompted earlier intervention. Therefore, although encouraging, we consider the presented experience as preliminary, and a starting point for further studies to help define more selective algorithms that embrace the ALARA principle. This is particularly true for important injuries not seen in this series, such as penetrating trauma, ureteropelvic junction disruption and avulsion or thrombosis of the renal pedicle. Even so, based on our experience it appears that liberal use of CT over US would lead to a high number of studies to detect or better define few abnormalities, particularly if obtained for patients with low grade injuries.

An important criticism behind the use of ultrasound is that it lacks sensitivity and diagnostic accuracy, particularly if used instead of CT at the time of presentation. This problem is compounded by the lack of intravenous contrast enhancement, dependence on technical expertise and patient related limitations (ie motion, body habitus) distinctive of US evaluation. By not routinely repeating CT, disruptions in the collecting system are detected as enlarging perinephric fluid collections (fig. 4), and vascular injuries or areas of renal parenchymal compromise are evaluated by Doppler US. Potentially, the diagnosis may be delayed since confirmatory studies or interventions are needed in some circumstances, for example in the case of an enlarging or symptomatic urinoma contrast CT, retrograde pyelography or

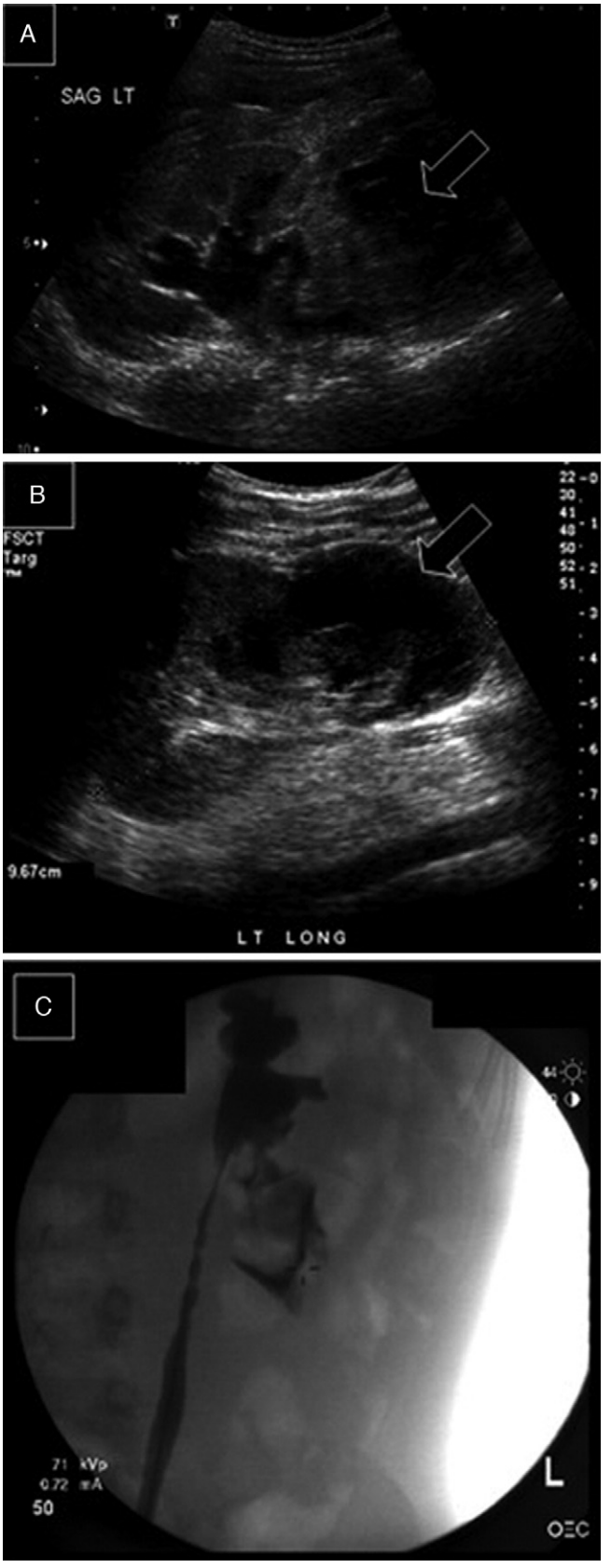

Figure 4. Images obtained during evaluation and treatment of 1 patient with enlarging urinoma (arrows) following PBRT, suspected on serial US (*A* and *B*), confirmed at retrograde pyelography (*C*) and treated with placement of ureteral stent.

percutaneous aspiration and analysis would be performed. Nevertheless, it is reassuring that some literature would suggest that delayed intervention in the setting of blunt abdominal trauma is not associated with worse outcomes.[17]

As technology improves and protocols are standardized, the gap between these imaging modalities may narrow and help favor the more liberal use of followup US.[18] This point awaits further study for the management of associated (nonurological) injuries, as we must conform to the recommendations of the trauma team regarding the need for repeat scanning in those cases. As more physicians become sensitized to the potential overuse of CT, efforts at reducing its use will likely impact the monitoring of patients with other abdominopelvic organ injuries.[10] The role of US in pediatric trauma is continuously being reevaluated and is likely to expand in the future. Undoubtedly, some children will benefit from repeat evaluation with CT. However, a more selective approach appears prudent, perhaps by continuing efforts at better selection based on patterns detected at presentation.[19]

This series has the limitations inherent in a retrospective study, as it was a chart review from the pediatric trauma database at a single center. It centered on PBRT and, thus, application to trauma to other abdominal or pelvic organs is restricted. Also, economic considerations were not evaluated but may prove to be important in our current cost containment environment. Furthermore, the use of US was not included in an established protocol, but rather was progressively introduced in an effort to decrease radiation exposure on a case-by-case basis. In addition, children with grade 1 and 2 injuries could have been monitored without repeat imaging studies, as the yield of detecting abnormalities that would require attention is particularly low if the patient is clinically stable. Lastly, there is potential value in the use of other imaging studies (eg nuclear renal scans),[20] which were not routinely obtained in our series.

CONCLUSIONS

Our experience suggests that after initial CT in patients with PBRT acute surveillance can be performed with US in most instances (excluding patients with hemodynamic instability or deemed to require CT for associated injuries). Selective reevaluation with CT can be reserved for those with abnormalities detected on serial US. Application of the ALARA principle appears feasible in the setting of PBRT.

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EDITORIAL COMMENT

For most of my medical career CT was good for you. Now, it is increasingly obvious that CT involves a small but real cancer risk. The younger the patient, the higher the (lifetime) risk. The actual lifetime cancer mortality risk is unknown but hovers around 0.08% for a single adult abdominal scan, more than doubling to 0.18% for a single pediatric abdominal scan (reference 4 in article). For those whose disease requires serial imaging the predicted cancer mortality risk can increase to 1.9% for a lifetime of annual scans (30 scans).[1]

This study has a 2-armed effect. The first is to get us to think about reducing the risk of iatrogenic cancer in our pediatric trauma patients, even as we are working hard to decrease the risk of harm from the trauma itself. That means we have to abandon the idea that "CT is good for you," and realize that the potential beneficial information expected from each scan must be weighed against the potential of a cancer death decades down the line. It will not be easy.

The second effect of this report is to quantify just how often followup scans are required in pediatric blunt renal trauma. I recommend followup scans only if the condition changes for the worse (unexplained fever, flank pain, suspected urinoma, decreasing hematocrit etc) and, thus, I order a small number of unnecessary scans. In this series that small number was reduced further—even the 4 of 71 patients (6%) with symptomatic urinomas avoided repeat CT. Of the remaining patients 85% did not undergo repeat CT, 12% underwent repeat CT for other nonurological reasons and 3% underwent CT just for the kidney.

Most children do well after blunt renal trauma, and in the absence of clinical deterioration do not require followup CT. Followup CT can be further reduced by using ultrasound to diagnose those 6% of patients with suspected urinoma (most of whom will be cured with a stent). This report makes it clear that it is time to let ALARA into your life, even in the trauma patients.

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