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Imaging for Cerebral Edema in Diabetic Ketoacidosis: Time to Zap the CT?

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Cerebral edema is a serious complication of diabetic ketoacidosis (DKA) and although mental status abnormalities occur in cerebral edema. When obvious, as evidenced by signs of clinically evident signs of increased intracranial pressure such as altered mental status associated with systemic hypertension and bradycardia and Kussmaul respirations, clinicians can easily recognize and diagnose cerebral edema (1–4). However, subclinical cerebral edema is known to occur in DKA, and clinical signs may lack both sensitivity and specificity. Highlighting this clinical challenge, in 1981, Elliot Krane discussed that while clinicians are aware of cerebral edema, clinically apparent cerebral edema is in-fact rare and difficult to clinically diagnose. In this series which suggested a utility for the use of head CT scans to aid in the diagnosis of cerebral edema, Krane showed that compared with the scans during convalescence, the early head CT scans of all six children who received fluids and low dose resuscitation showed a narrowing of the brain's ventricular system which was compatible with brain swelling. He also reported subjective narrowing of the subarachnoid spaces. Both these findings, he argued, suggested that subclinical brain swelling may be a common occurrence during pediatric DKA treatment (5). This report, while small, was influential in guiding modern imaging practice in acute DKA evaluation and treatment. Since then, a number of articles have been published on whether or not and how to use head CT scans to confirm the present cerebral edema, as this diagnosis would then drive downstream decisions for triage to the intensive care unit, escalate monitoring, and/or lower thresholds for consideration of treatment for potential high intracranial pressure, resulting from cerebral edema. Furthermore, these children are at risk of sudden death, which renders timely diagnosis extremely important.

However, a few secular trends have affected how we consider the role of head CT imaging in pediatric DKA. *First*, increasing concerns for the responsible use of head CT scans and radiation exposure have resulted in national campaigns such as the “Image Gently Campaign” that advocate limiting the number of head CTs performed in children regardless

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of condition, optimization of imaging protocols, and limiting time in the scanner to reduce both parental anxiety and the potential of cancer (6). *Second*, the landmark 2009 study by Kupperman and colleagues validated prediction rules that identified children at very low risk of clinically insignificant traumatic brain injuries for whom CT could routinely be obviated (7). Although a different condition and not validated in DKA related cerebral edema, many children with DKA receive neurological assessments using the Glasgow Coma Scale score. This begs the question as to whether or not children with DKA patients with reassuring Glasgow Coma Scale scores, comparable to mild traumatic brain injury, require head CT imaging. *Third*, magnetic resonance imaging technology use has gained both in popularity and in clinician acceptance as a tool to diagnose subclinical cerebral edema and to increase our understanding brain pathophysiology in DKA (8,9). However, need for sedation and lack of urgent magnetic resonance imaging pose barriers to timely use of this technology. This leaves us with head CT as the most rapidly accessible and reliable imaging technology available for use in the early evaluation of children with DKA.

In this month's journal article, "Suspected Cerebral Edema in Diabetic Ketoacidosis: Is there still a role for Head CT in treatment decisions?", Soto-Rivera examined biochemical, radiographic and clinical data from 686 patients under the age of 26 years who received care between 2004 and 2010. They found a 14% prevalence of altered mental status, occurring more often in patients who were younger, and were more critically ill (10). Head CT was performed in 60 (63%) patients with altered mental status; of which 27% had abnormal head CT results. Hyperosmolar therapy was given in 23 of the 60 patients (38%), of which 12 (52%) had normal head CT results, 8 of these 12 (67%) after cerebral edema treatment and 4 (33%) before. Of the 11 admissions with abnormal head CT results associated with receipt of hyperosmolar therapy, 4 head CTs (36%) occurred after hyperosmolar treatment and 7 (64%) occurred before treatment. For the 11 admissions with head CT before cerebral edema treatment, there was a median 2-hour delay between head CT and hyperosmolar therapy. The authors concluded that there was no evidence that decisions about treatment of patients with DKA and suspected cerebral edema were enhanced by head CT, and that head CT may have led to a significant delay in hyperosmolar therapy. These findings raise important questions regarding the utility of head CT for the detection of cerebral edema in DKA. The study highlights that while head CT is obtained to diagnose cerebral edema, decisions about treatment of patients with DKA and suspected CE are not affected by head CT results and, in-fact, obtaining a head CT may have led to a significant delay in hyperosmolar therapy. Additionally, authors provide a table of reasons why clinicians did not treat altered mental status despite an abnormal head CT; most reasons included improvement in clinical examination. Conversely, more than half of the patients (63%) with a normal head CT after initial treatment for CE received a second or more doses of hyperosmolar treatment. Together, these findings suggest that secular trends noted above have resulted in clinicians not ordering and using head CT scan results in the same way as in past decades.

The study has some methodological issues that merit discussion. Multiple radiologists examined the head CT scans, which may have introduced variability in the diagnosis of abnormal findings. Delay in treatment was defined from time of head CT scan rather than time of altered mental status. However, this was unavoidable due to the retrospective nature of the study and whatever bias was introduced because of this would only have

underestimated the delay time. The data are a few years old and ISPAD guidelines were published serially in 2000, 2009, 2014 (11–13). However, their recommendations that head CT imaging occur after treatment is initiated have not changed over time. Despite study limitations, these investigators have contributed important information to the literature regarding what we would call health services research in pediatric DKA. While we are not quite ready to zap head CT scans completely in the treatment of pediatric DKA, this study suggests that clinicians are relying more heavily on the neurological examination even when CT scans are obtained, and that further work is to be done to implement ISPAD recommendations on treatment before imaging. Efforts to refine and validate the neurological examination for DKA and reduce treatment delays due to imaging waits may be required to provide best practice and timely care to DKA patients at risk of cerebral edema.

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