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Review Article

Pediatric Computed Tomography Dose Optimization Strategies: A Literature Review

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ABSTRACT

Introduction: Computed tomography (CT) dose optimization is an important issue in radiography because CT is the largest contributor to medical radiation dose and its use is increasing. However, CT dose optimization for pediatric patients could be more challenging than their adult counterparts. The purpose of this literature review was to identify and discuss the current pediatric CT dose saving techniques. Optimized pediatric protocols were also proposed.

Methods: A comprehensive literature search was conducted using the Medline, ProQuest Health and Medical Complete, PubMed, ScienceDirect, Scopus, Springer Link, and Web of Science databases and the keywords CT, pediatric, optimization, protocol, and radiation dose to identify articles focusing on pediatric CT dose optimization strategies published between 2004 and 2014.

Results and Summary: Seventy-seven articles were identified in the literature search. Strategies for optimizing a range of scan parameters and technical considerations including tube voltage and current, iterative reconstruction, diagnostic reference levels, bowtie filters, scout view, pitch, scan collimation and time, overscanning, and overbeaming for pediatric patients with different ages and body sizes and compositions were discussed. An example of optimized pediatric protocols specific to age and body size for the 64-slice CT scanners was devised. It is expected that this example could provide medical radiation technologists, radiologists, and medical physicists with ideas to optimize their pediatric protocols.

RÉSUMÉ

Introduction : L'optimisation de la dose en tomodensitométrie (TDM) est un enjeu important en radiographie, puisque la TDM est le principal contributeur de dose de radiation médicale et que son utilisation est en croissance. Cependant, l'optimisation de la dose en TDM pour les patients pédiatriques pourrait être encore plus difficile que pour les patients adultes. Le but de cette revue de littérature est de recenser les techniques actuelles d'économie de dose en TDM pédiatrique et d'en discuter. Des protocoles pédiatriques optimisés sont également proposés.

Méthodologie : Une revue de littérature complète a été effectuée dans les bases de données Web of Science, Medline and ScienceDirect en utilisant les mots-clés suivants: TDM, pédiatrie, optimisation, protocole et dose de radiation, afin d'identifier les articles portant sur les stratégies d'optimisation de la dose en TDM pédiatrique publiés entre 2004 et 2014.

Résultats et résumé : Soixante-treize articles ont été recensés dans la revue de littérature. Les stratégies d'optimisation d'un éventail de paramètres de balayage et des considérations techniques comme la tension et le courant du tube, la reconstruction itérative, les niveaux de référence diagnostiques, les filtres papillon, les topogrammes, le pas, la collimation et le temps pour le balayage et la concentration du faisceau sur des patients pédiatriques d'âge, de taille et de composition corporelle variables ont fait l'objet des discussions. Un exemple de protocole pédiatrique optimisé spécifique selon l'âge et la composition corporelle pour le scanner Siemens Sensation 64 a été conçu. On prévoit que cet exemple pourrait fournir des idées plus solides aux radiographes, aux radiologistes et aux physiciens médicaux dans la poursuite de l'optimisation de leurs protocoles pédiatriques.

Keywords: Computed tomography; pediatric; optimization; protocol; radiation dose

Introduction

Computed tomography (CT) dose optimization is an important issue in radiography because CT is the largest contributor to medical radiation dose and its use is increasing [1, 2].

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However, CT dose optimization for pediatric patients could be more challenging than their adult counterparts because children are more radiosensitive to radiation [3]; they have longer lifetimes, allowing potential radiation effects to manifest [4]; and there are large variations of body size and composition (percentages of fat, muscle, and bone) within each age group and across different groups [5–7]. Some clinical centers have implemented age- and child-size–specific CT scan protocols, and their effect on dose reduction has been recognized [5, 8, 9]. However, variations of these age- and child-size–specific protocols exist, which makes it difficult for other departments to follow them [5–12]. Also, there is a lack of standardization with respect to the definition of pediatric patients. One of the common definitions defines pediatric patients as those aged 0–15 years [13–15]. This definition is used in the present article.

The purpose of this literature review was to identify and discuss the current pediatric CT dose saving techniques. Optimized pediatric protocols and further study directions were also proposed. It is expected that this review could potentially increase the awareness of medical radiation technologists on the range of dose saving techniques available in the literature and encourage them to optimize their protocols, reducing the risk of pediatric CT examinations.

Methods

A comprehensive literature search was conducted using the Medline, ProQuest Health and Medical Complete, PubMed, ScienceDirect, Scopus, Springer Link, and Web of Science databases and the keywords CT, pediatric, optimization, protocol, and radiation dose to identify articles focusing on pediatric CT dose optimization strategies. The article inclusion criteria were as follows: (1) published between 2004 and 2014, (2) original research article, (3) peer reviewed, and (4) written in English. Articles were excluded if they belong to conference abstract and commentary. Figure 1 shows the literature search process.

Results and Discussion

Seventy-seven articles were identified in the literature search and covered a range of areas including pediatric CT protocols specific to age, body size, and composition; scan parameters that influence radiation dose and image quality; and other technical considerations (Figure 1). They are discussed in the following sections.

Protocols Specific to Age, Body Size, and Composition

According to the International Atomic Energy Agency survey of pediatric CT practices in 40 countries published in 2013 [13], more than half of the clinical centers relied on preprogrammed scan protocols provided by manufacturers. In most of these scan protocols, specific techniques are suggested for each patient age group because it is assumed that body sizes and compositions (percentages of fat, muscle, and bone) of patients within the same age group should be similar. However, recent studies indicated that even in the same age group there are great variations of body size and composition because of factors such as obesity [5–21].

Since the last decade, some manufacturers and clinical centers have started to optimize their protocols based not only on patient age, but also their body size in terms of weight. This is known as the color-coded system [9]. The scan settings such as tube potential and current and exposure time are tailored to specific patient conditions, leading to lower dose and better image outcome. However, this approach requires medical physicists possessing sound knowledge of scanner specifications with support from radiologists and medical radiation technologists to develop these optimized protocols, which is not feasible in many health institutions [13, 22].

Patient size parameters such as weight and body mass index are commonly used for developing size-specific protocols for pediatric and adult patients. Recently, effective diameter and cross-sectional dimension have been considered as more accurate indicators of body size and habitus [5–7]. Also, awareness about variation of organ radiosensitivity across the child age range as

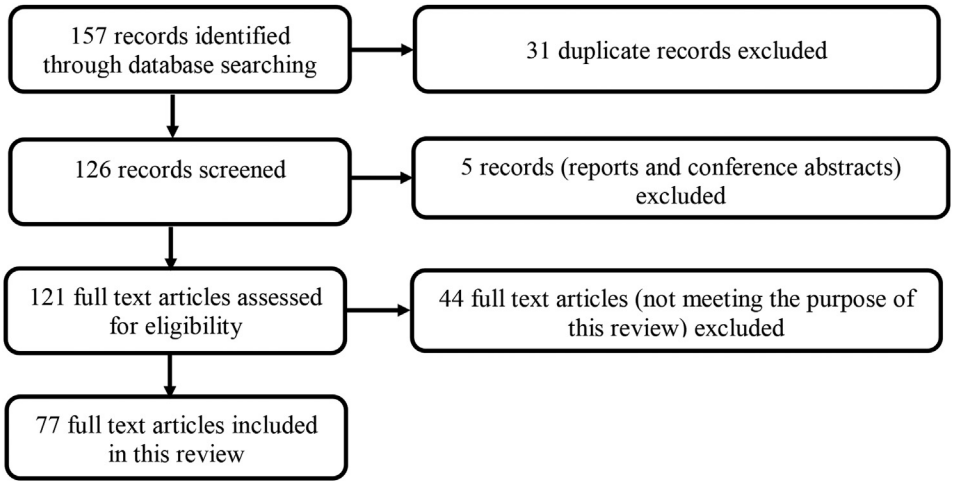

Figure 1. Flowchart showing the article identification and selection process.