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Review article

Radiation dose in paediatric cardiac catheterisation: A systematic literature review

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ABSTRACT

Objectives: It is believed that children are more sensitive to ionising radiation than adults. This work reviewed the reported radiation dose estimates for paediatric cardiac catheterisation. A systematic literature review was performed by searching healthcare databases for studies reporting radiation dose using predetermined key words relating to children having cardiac catheterisation. The quality of publications was assessed using relevant Critical Appraisal Skills Programme questions and their reported radiation exposures were evaluated.

Key findings: It is only in recent years that larger cohort observations have been undertaken. Although radiation dose from paediatric cardiac catheterisation has decreased in recent years, the literature indicated that it remains varied and potentially substantial.

Conclusion: Standardisation of weight categories and procedure types such as those recommended by the PiDRL project could help compare current and future radiation dose estimates.

Introduction

Children undergoing paediatric cardiac catheterisation (PCC) receive essential diagnosis and treatment of congenital heart disease (CHD). The greatest radiation doses may occur during complex procedures, which are likely to involve longer fluoroscopy time (FT) and more digital acquisitions. Radiation exposures in PCC are justified because the benefit outweighs the risk in accordance with national and European guidelines.[1,2] A number of factors affect radiation dose including the type and complexity of CHD, imaging protocols, X-ray equipment, and operator experience. Furthermore, there exists a large variation in patient size, as well as type of radiation dose units used for dosimetry, potentially causing confusion for clinicians. The continuing development of new technology may affect the radiation dose in PCC. During the last decade there have been major technological advances in surgical equipment used such as the amplatzer closure device for patent ductus arteriosus (PDA) interventions.[3] Likewise, imaging equipment in developed countries has transitioned from the use of image intensifier (II) to flat panel detector (FPD) technology. A recent survey of clinical centres in the United Kingdom (UK) (n = 13) and Ireland (n = 1) demonstrated more than half of surveyed centres were using FPDs during PCC.[4] A review of published radiation doses in PCC is necessary to provide an accurate depiction of clinical radiation exposures. The aim of our work was to perform a systematic literature review to determine the current radiation doses reported from PCC.

Methodology

The systematic literature search was performed using the following healthcare databases: Medline (1949 – present), Pubmed (1947 – present), Science Direct (1823 – present), Cumulative Index to Nursing and Allied Health (CINAHL) (1937 – present) and the Cochrane Library Database (1974 – present). The Transparent Reporting of Systematic Reviews and Meta-Analysis group flow chart demonstrates the search strategy used[5] (Fig. 1). The "Medical Subject Heading" (MeSH) was used to help identify related keywords (Table 1). The reference list of each relevant article was searched for additional publications and a zetoc alert was set up to identify current and future publications (www.zetoc.mimas.ac.uk). Identified articles were included if they were in English, measured radiation dose in PCC and were fully peer reviewed. Articles were excluded if they were review articles or if they only observed dose in patients >18 years of age. Each study was assessed by one reviewer using a scoring scale based on seven relevant cohort study Critical Appraisal Skills Programme (CASP)[6] as follows: (i) Did the

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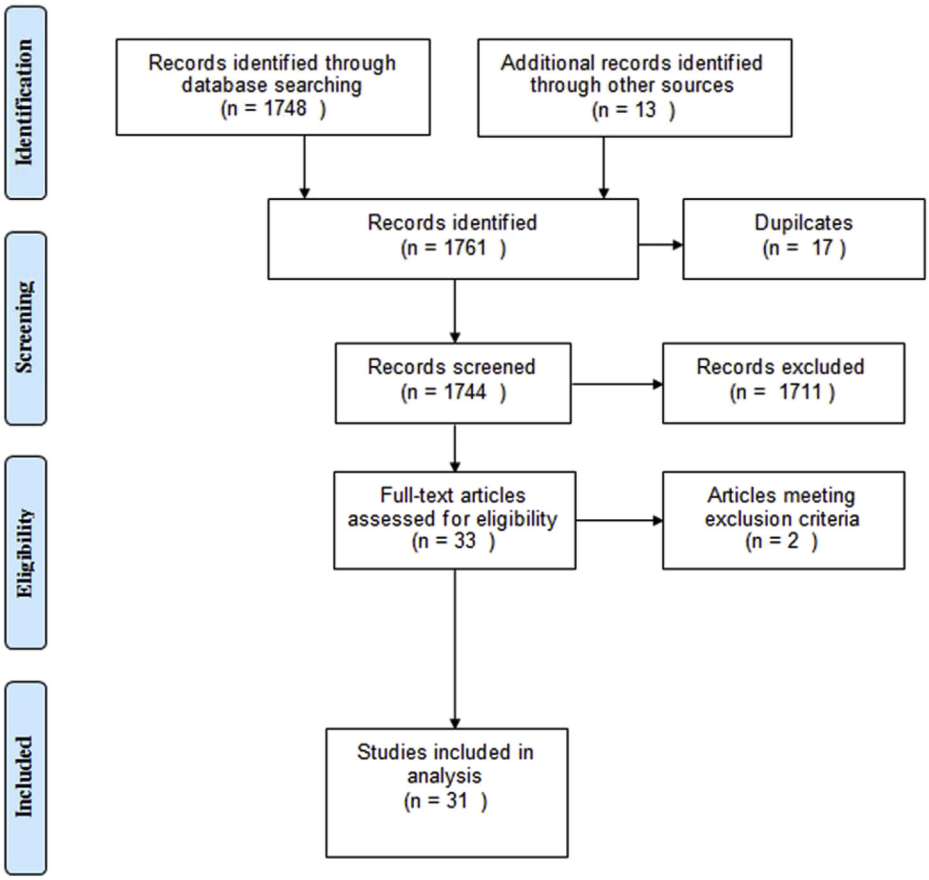

Figure 1. Summary of literature review search using the Transparent Reporting of Systematic Reviews and Meta-Analysis group flow chart (2009).

Table 1
Summary of keywords searched in the systematic literature review.

1st term	2nd term	3rd term
Pediatric	Cardiac	Radiation dose
OR	OR	OR
Paediatric	Catheterization	Radiation exposure
OR	OR	OR
Newborns	Catheterisation	Radiation protection
OR	OR	OR
Adolescents	Cardiology	Radiation injuries
OR	OR	OR
Infants	Interventional cardiology	Reference levels
OR		OR
Children		Dose reduction
OR		OR
Congenital heart disease		Dose optimization
OR		OR
		Dose optimisation
		OR
		Ionising radiation
		OR
		Ionizing radiation
		OR

study address a clearly focused issue? (ii) Was the cohort recruited in an acceptable way? (iii) Was the radiation dose accurately measured to minimise bias? (iv) Have the authors identified and taken into account confounding factors? (v) Do you believe the results? (vi) Can the results be applied to the local population? (vii) Do the results of the study fit with other available evidence? Two additional reviewers assessed the resultant scores given by reviewer one.

Results

The literature search results are summarised in Table 2. The additional reviewers had no disagreements with the scoring of article quality. Thirty-one relevant articles were reviewed. These included studies relating to radiation dose, dose optimisation, risk estimates, biological effects and image quality. Approximately 50% of studies were published from 2010 to 2015 yet accounted for 95% of the data observed in the literature. The smallest studies consisted of 18 children[7,8] whilst the largest studies were performed in the United States of America (USA) and UK and consisted of 8267 and 7726 children respectively.[9,10] The most commonly observed measurements were dose area product (DAP) (n = 26) and FT (n = 23). More studies provided data using an II (n = 18) compared to a FPD (n = 12). The majority of studies presenting data from FPDs (n = 12) were published in the last five years (n = 9). The CASP quality scores were consistently high. All articles scored between five and seven with a mean score of six. Radiation dose estimates by Verghese et al[11] (n = 3365) and Harbron et al[10] (n = 7726) demonstrated a decline in radiation doses in PCC from 2004 to 2008. All but two small studies[12,13] stated they had calibrated or performed quality assurance on their either their DAP meters or radiographic film.

Articles presenting DAP as mean or median are demonstrated in Tables 3 and 4. The majority of studies (90%) observed greater DAP from interventional procedures compared to diagnostic. Mean diagnostic DAP ranged from 294 cGycm^2[14] to 2080 cGycm^2.[8] Mean DAP for interventional procedures ranged from 312.9 cGycm^2[14] to 10,900 cGycm^2.[8] Median interventional DAP was as high as 30,067 cGycm^2. This occurred with patients >16 years undergoing

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