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Review

Systematic review of the safety and efficacy of contrast injection via venous catheters for contrast-enhanced computed tomography

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ABSTRACT

Objective: To examine the safety and efficacy of contrast injection through a central venous catheter (CVC) for contrast-enhanced computed tomography (CECT).
Methods: A systematic literature search was performed using PubMed. Studies were deemed eligible if they reported on the use of CVCs for contrast administration. Selected articles were assessed for their relevance and risk of bias. Articles with low relevance and high risk of bias or both were excluded. Data from included articles was extracted.
Results: Seven studies reported on the use of CVCs for contrast administration. Catheter rupture did not occur in any study. The incidence of dislocation ranged from 2.2-15.4%. Quality of scans was described in three studies, with less contrast enhancement of pulmonary arteries and the thoracic aorta in two studies, and average or above average quality in one study. Four other studies used higher flowrates, but did not report quality of scans.
Conclusion: Contrast injection via CVCs can be performed safely for CECT when using a strict protocol. Quality of scans depended on multiple factors like flow rate, indication of the scan, and cardiac output of the patient. In each patient, an individual evaluation whether to use the CVC as access for contrast media should be made, while bolus tracking may be mandatory in most cases.

1. Introduction

Central venous catheters (CVCs) are frequently used in critically ill patients requiring continuous intravenous infusions. In many of those patients, CVCs remain the only venous access site, because placement of peripheral intravenous catheters is challenging due to edematous states or recurrent phlebitis. CVCs are also used in patients in need of frequent intravenous access or when toxic drugs need to be administered. Different types of CVCs exist: classic and most frequently used non-tunneled and tunneled CVCs, implantable ports, and peripherally inserted central catheters (PICC) [1]. Each type of catheter has its own maximal flowrate and pressure limit according to the manufacturer [1]. When present, CVCs are the easiest way for the administration of iodine-based contrast for performing enhanced computed tomography (CECT) examinations. Standard CT injection protocols require contrast volumes ranging from 75 to 150 mL with an injection rate between 3 and 5 mL/s [2]. Currently, most manufacturers of CVCs do not recommend high flow rates via CVCs, due to the risk of rupture, displacement, contrast media extravasation, catheter dysfunction, and thrombosis [3,4]. Several manufacturers produce CVCs specifically designed for so-called power injection [5–8]. This systematic review evaluates whether CVCs can be safely used for the administration of intravenous contrast agents, particularly at higher injection rates for obtaining high-quality images.

2. Methods

2.1. Search strategy and selection

A systematic literature search was performed on September 10th, 2016 using PubMed. A search query was built by linking two content areas: 'central catheter' and 'contrast enhanced' with relevant synonyms for both areas: **((central line [Title/Abstract] OR central catheter [Title/Abstract] OR CVC [Title/Abstract] OR central venous [Title/Abstract] OR PICC [Title/Abstract] OR port-a-cat* [Title/Abstract] OR PAC [Title/Abstract] OR Port a cath [Title/Abstract]**

Abbreviations: CVC, central venous catheter; CECT, contrast-enhanced computed tomography; PICC, peripherally inserted central catheter; TIVAP, totally implantable venous access ports; SVC, superior vena cava; PIPICC, power injectable peripherally inserted central catheter; CT-PICC, CT-injectable peripherally inserted central catheter

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OR jugular line [Title/Abstract] OR jugular catheter [Title/Abstract] OR subclavian line [Title/Abstract] OR subclavian catheter [Title/Abstract])) AND (CT [Title/Abstract] OR CECT [Title/Abstract] OR contrast enhanced [Title/Abstract] OR contrast-enhanced [Title/Abstract] OR power injection [Title/Abstract] OR power injector).

PubMed was searched systematically to identify original publications on the use of CVCs for contrast administration for CT-scans focusing on safety, efficacy, and complications. Exclusion criteria included: no full-text available, publication not written in English or Dutch, review articles, case reports, and studies focusing on the use of CVCs in pediatrics. Duplicate publications were excluded. A cross-check of reference lists from selected articles was performed to identify articles missed by the initial search. Screening of title, abstract, and full text was performed by two authors (SBB, MWB) independently. Disagreements were discussed until consensus was reached. The reference lists of the selected articles were hand searched for relevant cross-References

2.2. Study assessment

The remaining articles were assessed for their relevance and risk of bias by two authors (SBB, MB) independently using predefined criteria (Table 1). Studies were classified as highly relevant if they complied with all criteria and moderately relevant if the reported outcome only included safety or efficacy. Studies were classified as having low risk of bias if they satisfied all criteria and high risk of bias if they satisfied less than three criteria. The remaining studies were classified as having a moderate risk of bias. Studies were only included for further analysis if they scored high or moderate on relevance and carried a low or moderate risk of bias. Discordances were discussed until consensus was reached.

2.3. Data analysis

Incidences of complications were extracted from the selected studies were tabulated and presented as percentages. Data on quality of images was extracted where applicable. Numerators and denominators were provided when reported in the articles.

3. Results

3.1. Search and selection

The literature search yielded 484 unique hits. Twenty-three articles were considered eligible for answering the research question after selection based on title and abstract. Seventeen articles were excluded during full text screening because of the following reasons: incorrect domain (n = 1) [9], outcome not focusing on safety, efficacy, and complications (n = 1) [10], CVC use in pediatrics (n = 7) [11–17], in vitro studies (n = 4) [18–21], no original article (n = 3) [1,22,23], and not meeting language requirements (n = 1) [24]. During cross referencing, one study was included missed by the initial search [25]. Eventually, eight studies were eligible for critical appraisal (Table 1) [3,25–31].

3.2. Study assessment

Three studies scored high on relevance [25,30,31] and five scored moderate on relevance [3,26–29]. The risk of bias was low in one study [30], moderate in six studies [25–29,31], and high in one study [3] (Table 1). Carlson et al. [3] evaluated the system pressure in thirteen patients with Port-A-Caths. The pressure measurement was not standardized: five patients' injection pressures were measured with a pressure gauge that was placed in-line during injection and eight patients' injection pressures were not. They did not report on the quality of the CT images and only one sentence addressed the absence of complications. The lack of standardization and limited relevance made us decide to exclude this study from data analysis. Finally, seven studies [25–31] were included for further analysis (Table 2).

3.3. Data analysis – safety

The study characteristics and main results are presented in Table 2. Coyle et al. [31] found two (2/110; 1.8%) externally ruptured PICCs while injected at a rate of 2 mL/sec. However, the ruptures were caused by mechanic obstructions; i.e. one of the ruptured PICCs was clamped, the other kinked at the venous entry site. Another PICC ballooned without rupturing and further injected was stopped. Goltz et al. [25] evaluated power injections in 141 patients with totally implantable venous access ports (TIVAPs) in their forearm. One (1/141; 0.7%) TIVAP's tip was dislocated in the brachiocephalic vein and revealed a catheter rupture during an interventional retrieval attempt. Three (3/

Table 1
Study assessment.

Study (year)	Relevance			Risk of bias				Included for analysis
	Patients	Outcome: safety	Outcome: efficacy	Standardization of test	Blinding	Selective reporting	Complete data	
Carlson et al (1992)[3]	●	●	○	○	NA	●	●	No
Coyle et al (2004)[31]	●	●	●	●	○	●	●	Yes
Goltz et al (2011)[25]	●	●	●	●	○	●	●	Yes
Herts et al (2001)[30]	●	●	●	●	●	●	●	Yes
Lozano et al (2012)[28]	●	●	○	●	NA	●	●	Yes
Macht et al (2012)[26]	●	●	○	●	NA	●	●	Yes
Morden et al (2014)[29]	●	●	○	●	NA	●	●	Yes
Sanelli et al (2004)[27]	●	●	○	●	NA	●	●	Yes

NA = not applicable
Relevance
Patients: ● = patients with a central catheter
Outcome: safety: ● = data on complications, injection rate and pressure; ○ = data on either complications, injection rate and pressure
Oucome: efficacy: ● = data on quality of images; ○ = no data on quality of images
Risk of bias
Standardization of test: ● = yes; = no
Blinding: ● = reviewer of quality of the images was blinded for route of injection; ○ = reviewer was not blinded
Selective reporting: ● = adequate sample selection; ○ = inadequate sample selection
Completeness of outcome data: ● < 10% missing data; ○ > 10% missing data