Head-to-head comparison of prospectively triggered versus retrospectively gated coronary CT angiography: Meta-analysis of diagnostic accuracy, image quality, and radiation dose

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Purpose

Coronary catheter angiography is the gold standard for assessing coronary stenoses in coronary artery disease (CAD), but is invasive and cost-intense. It can be cost-effective and clinically useful to preselect patients with an intermediate pretest probability for CAD by non-invasive coronary computed tomography angiography (CTA), so that invasive coronary catheter angiography focuses on the truly diseased patients [1].

In suitable patients the required radiation dose of coronary CTA can be reduced when using prospective electrocardiography (ECG) triggering instead of retrospective ECG-gating. In traditional retrospective gating all cardiac phases are imaged. With traditional prospective triggering the heart is imaged in a predefined cardiac phase, which requires less radiation dose but provides just one cardiac phase for interpretation. However, both descriptions are just extremes among different options, which also comprise the mixing of prospective with retrospective components: Retrospective gating can be used with tube current modulation, where the tube current is (prospectively ECG-based) reduced in some cardiac phases; and prospective triggering is applicable with temporal padding for retrospective reconstructing of a small range of cardiac phases [2].

Retrospective gating acquires more CT data and consequently causes more radiation dose than prospective triggering. Prospective triggering is most suitable in patients with regular heart rate of #75 beats per minute, when using a modern #64-slice single-source CT with a temporal resolution of 140-210 milliseconds. Dual-source CT with its high temporal resolution of #83 milliseconds allows prospective triggering also at high heart rates [3].

In patients with CAD symptoms and potential eligibility for prospective triggering (e.g., without tachyarrhythmia), several primary studies have performed a head-to-head comparison of prospectively triggered versus retrospectively gated CTA in two groups that had similar patient characteristics. The purpose of this meta-analysis was to summarize the published evidence from those studies about image quality, diagnostic accuracy, and radiation dose for the comparison of prospective triggering versus retrospective gating in coronary CTA [4].

Methods and Materials

PubMed and 3 other databases were searched from 2007 to May 2012 without language restrictions. In CAD patients without tachyarrhythmia, eligible studies compared prospectively triggered versus retrospectively gated CTA (performed with #64-slice CT or
dual-source CT) in 2 groups having approximately similar patient characteristics, scored CTA image quality, and/or assessed how accurately CTA diagnoses #50% coronary stenoses compared to catheter angiography, and reported the mean effective radiation dose. Study selection and data extraction was independently performed by two readers, with disagreement solved in consensus. The following radiation dose equations were used, if any parameter was not reported but could be recalculated from other reported parameters (Figure 1):

\[
(1) \text{DLP} = \text{CTDI}_{\text{VOL}} \times L \quad \text{and} \quad (2) \ E = k \times \text{DLP}
\]

with DLP = dose length product (mGy \times cm); \text{CTDI}_{\text{VOL}} = \text{volume CT dose index (mGy)};
L = \text{scan length (cm)}; \ E = \text{effective dose (mSv)};
\]

\[
k = 0.017 \text{ mSv} \times \text{mGy}^{-1} \times \text{cm}^{-1} \quad \text{(conversion factor of the chest)}
\]

Fig. 1: Radiation dose calculations.


The effective dose (E) was normalized to \( k = 0.017 \), if another conversion factor had been used. Count data for image quality and diagnostic accuracy were evaluated on the segment-level, artery-level, and patient-level, as available. This meta-analysis applied a 3-point score for image quality. Score 1 (non-diagnostic) indicates severe artifacts that prevent a diagnosis. Score 2 (fair-to-good quality) indicates moderate-to-mild artifacts that permit a diagnosis, and score 3 (excellent quality) indicates no artifacts. The items of the QUADAS tool (QUality Assessment of Diagnostic Accuracy Studies) were adapted to assess the methodological study quality and sources of bias [5]. Univariate summary estimates of image quality and bivariate summary estimates of sensitivity and specificity were obtained from random-effects models, using PROC GLIMMIX from SAS 9.3 with the gating/triggering method as covariate [6,7]. Additionally, subgroup analyses were performed with the study characteristics as covariates, and causes of non-diagnostic findings were summarized.

Results

The literature search identified 10254 sources. Twenty studies were selected (Figure 2). They generally showed high methodological quality. No publication bias was observed (P>0.05).
Fig. 2: Literature search and selection. The diagram shows the study flow, and the table presents the PubMed search terms.


Summary of meta-analytic results

The meta-analytic results are summarized in Table 1.
Table 1: Summary estimates of the meta-analysis.


**Image quality of coronary CTA**

The 20 studies had included 3330 patients. In total, 91.3% of CTAs (segments: 97.8%) had diagnostic quality with prospective gating and 93.3% of CTAs (segments: 98.4%) with retrospective gating (non-significant differences, P>0.05). The subgroup analyses showed some small differences between prospectively triggered and retrospectively
gated CTA (Figure 3). The percentage of diagnostic segments was best (P<0.05), when using retrospective gating with helical acquisition in the following CT systems: (a) 2x32-slice dual-source CT or 128-slice single-source CT, (b) a high temporal resolution of 83-165 milliseconds, and (c) z-flying focus technique. The other subgroup analyses showed no significant differences (P>0.05).

![Image](image.png)

**Fig. 3**: Image quality of coronary CTA at the (A) segment-level and (B) patient-level. These plots show the percentage of segments (A) and CTAs (B) with diagnostic quality, obtained by retrospective gating (horizontal axis) versus prospective triggering (vertical axis). Symbols: The diagonal lines are lines of identity. In each plot the meta-analytic summary estimate is indicate by a "+"-sign and is surrounded by its 95%-confidence ellipse. Each blue or orange circle represents a study, with circle area proportional to study size. When pooling all available study data, the differences between prospective triggering and retrospective gating were not significant (P>0.05). Only in a subgroup analysis dual-source CT or 128-slice CT with z-flying focus and a high temporal resolution (165 milliseconds or less) provided slightly better image quality when used with retrospective gating (P < 0.05). However, these differences were small and probably not relevant for clinical practice.


**Details of non-diagnostic segments**

The non-diagnostic segments were clustered in individual patients. On average, these patients had 4.0 non-diagnostic segments with prospectively triggered CTA and 3.7 non-diagnostic segments with retrospectively gated CTA. Nine studies reported causes of 371 non-diagnostic segments at CTA. In these patients stair-step artifacts (60 segments) and artifacts from premature beats (24 segments) were reported only in prospectively triggered CTA (P<0.01). The other causes for non-diagnostic segments affected both prospectively triggered and retrospectively gated CTA equally (P>0.05). These were
artifacts from calcifications (125 segments), motion (121 segments), proximal arterial occlusion (24 segments), image noise (12 segments), and venous overlap (5 segments).

**Diagnostic accuracy of coronary CTA**

Among 664 patients from 5 studies, the pooled sensitivity/specificity of coronary CTAs with diagnostic quality was 98.7%/91.3% (segment-level: 91.3%/97.7%) with prospective triggering and 96.9%/95.8% (segment-level: 93.1%/97.6%) with retrospective gating. The according differences were not significant (P>0.05) (Figure 4).

**Fig. 4**: Diagnostic accuracy of coronary CTA at the (A) segment-level and (B) patient-level. These plots show the specificity versus sensitivity of prospectively triggered and retrospectively gated CTA at the segment-level (A) and the patient-level (B). Symbols: The light-gray circles represent study groups with prospective triggering and the black circles represent study groups with retrospective gating, with circle area proportional to group size. In both plots the studies’ pooled summary estimate of sensitivity and specificity is indicated by a "+"-sign and is surrounded by its 95%-confidence ellipse. The bowed line is the summary receiver operating characteristics (ROC) curve. Regarding diagnostic accuracy there was no significant difference between both triggering/gating groups (P>0.05). However, at the segment-level (A) the specificity is generally high whereas the sensitivity is lower. At the patient-level (B) this relation is inverted. This finding is well known from other studies and their meta-analyses.


**Radiation dose of coronary CTA**

The pooled effective dose was 3.5 mSv with prospective triggering, and thus by a factor of 3.5 lower than the pooled effective dose of retrospective gating that was 12.3
mSv (significant difference, P<0.01). Table 1 provides further meta-analytic summary estimates.

Conclusion

In this meta-analysis the image quality and diagnostic accuracy of prospectively triggered versus retrospectively gated coronary CTA generally showed no significant differences, when using #64-slice CT or dual-source CT [4]. However, prospective triggering required much less radiation. This finding is relevant both to the CT-performing physician and the referring clinician, since both partners are responsible for the patient’s radiation protection that must be weighed against the need for diagnostic information [1]. In this situation it is favorable to choose the method with the lowest radiation exposure, if the results are similarly good.

In conclusion, for assessing coronary stenoses in patients without tachyarrhythmia by CTA, prospective triggering may be considered preferable over retrospective gating since it mostly provides similar image quality and diagnostic accuracy, but at a much lower radiation dose.

References


**Personal Information**