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Research article

CT-angiography in acute bleeding: Is a non-enhanced scan necessary?

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ABSTRACT

Objective: In clinical routine CT-angiography is frequently used to detect hemorrhage and to locate its source. Many centers use a triple phase protocol consisting of non-contrast, arterial and portal venous phase scan. The aim of this study was to clarify the added value of the non-contrast CT scan in detection of hemorrhage and to provide evidence for or against its usage.

Materials & Methods: We retrospectively included all patients between 2014 and 2020 who underwent triphasic CT angiography for suspected bleeding and interventional angiography within 6 h of CT confirming bleeding. Two experienced observers re-evaluated all CT scans and established consensus on whether the bleeding could confidently be detected without the non-enhanced CT scan. Additionally, we recorded data on radiation exposure.

Results: We included 75 patients (44 male, 31 female, median age 64 years) in the final dataset. Of all bleedings 33 (43 %) were GI bleedings. After consensus reading, non-enhanced CT scan was deemed helpful in only 3 cases (5.2 %) with all of these being GI bleeding. Non-enhanced series contributed substantially to the overall radiation exposure (mean $DLP_{non\ contrast}$ 927.9 mGy*cm, mean $DLP_{arterial}$ 631.3 mGy*cm, mean $DLP_{portal\ venous}$ 915.0 mGy*cm).

Conclusion: Our results suggest that in the vast majority of cases non-contrast CT is not necessary to detect hemorrhage. Omission of non-enhanced CT scans results in relevant dose reduction. However, in few cases non-contrast scan can be helpful to exclude false positive findings in particular in suspected gastrointestinal bleeding.

1. Introduction

Acute bleeding commonly occurs after trauma, surgical interventions or spontaneously, e. g. in case of gastrointestinal (GI) bleeding and is associated with a high mortality [1,2]. Therefore rapid detection of bleeding and in particular location of its source is crucial to timely initiate the appropriate therapy.

Historically conventional angiography has been used for diagnosis and – under circumstances – therapeutic intervention of active bleeding. However, due to its invasiveness, cost and the widespread use of CTs with the possibility of rapid vascular imaging (CTA, it is no longer used as general screening modality. Nowadays, computed tomography (CT), especially CT-angiography (CTA) is used as a non-invasive and widely available diagnostic tool in the evaluation of acute bleeding [3]. The accuracy of CT-angiography in detection of bleeding has been proven by numerous studies [4–8]. In many centers a triple phase protocol, consisting of a non-contrast, an arterial and a portal venous phase scan is considered the clinical standard. The basic idea of multiphase-CT in detection of bleeding is to provide detailed images of the blood vessels and surrounding tissues at different time points before and after the administration of contrast media. This allows to evaluate for hematoma, active bleeding in the sense of contrast extravasation and its source. The non-contrast scan is usually performed to be able to distinguish between contrast media at the bleeding site and other hyperdensities, such as calcification or foreign material [9].

However, there is no clear evidence for the non-contrast CT scan. Considering the additional radiation exposure, the omission of the non-enhanced phase could be beneficial for the patients.

The objective of this investigation was to evaluate the added benefit of non-contrast CT scans in identifying hemorrhage, while taking into account the extra radiation exposure it entails, and to present supporting or opposing evidence regarding its utilization.

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2. Methods

2.1. Patient characteristics and study design

Due to the retrospective study design and use of only anonymized data, the institutional review board waived the need for ethics approval / consent.

All patients who received CT for suspected bleeding and interventional angiography with confirmation of active bleeding between December 2014 and December 2020 were included. As per our institution's standard, CT scans had to be performed following a triphasic protocol, consisting of non-contrast, arterial and portal venous phase. Only cases that had interventional angiography within six hours after the CT scan were included to ensure that the bleeding visible on CT was indeed relevant.

2.2. Imaging-Protocol

Patients were scanned head-first supine on clinical CT (IQon and iCT Philips Healthcare) injecting 100 ml iodinated contrast media (Accupaque 350 mg/ml, GE Healthcare) into a cubital vein at a flow of 3,5–4 ml/s. Bolus tracking was used with a delay of 4,9 s for arterial and 49 s for portal venous phase after passing the threshold value of 150 HU in the descending aorta. Tube voltage was 120 kV for non-contrast, 100 kV (resp. 120 kV at IQon) for arterial and 120 kV for portal venous phase. Tube current modulation was used with mean mAs for the non-contrast scan set at 116 mAs, 83 mAs for the arterial and 116 mAs for the portal venous phase respectively. Slice thickness was 5 mm.

2.3. Subjective CT analysis

Image data were retrieved from the institution's Picture Archiving and Communication System (PACS) and analyzed using a standard DICOM viewer (ImpaxEE, Dedalus, Belgium) on dedicated workstations. All CT scans were re-evaluated by two radiologists with two and seven years of experience in emergency imaging. Readers were aware of the patients' medical history and the examination's clinical question but blinded to the radiological report. Initially, only the arterial and portal venous phase scans were examined, and only if necessary non-contrast scan was included in the evaluation. Each reader had to indicate whether a non-contrast scan was needed for each CT. After analysis of the CTs by the readers individually, consensus reading was performed to resolve disagreements.

The dose length product of each CT was recorded.

2.4. Statistical analysis

Statistical analysis was done using R (4.3.2) and RStudio (Version 2023.12.1 + 402). Comparison of radiation doses was done using ANOVA with TukeyHSD post-hoc testing. All p-values < 0.05 were considered significant.

3. Results

According to the inclusion and exclusion criteria, 75 patients were included for analysis (Fig. 1). 44 patients (59 %) were male and 31 female (41 %). Median age was 64 years.

Except for one case with a distal esophagus hemorrhage, all bleedings were abdominopelvic. Of all bleedings, 33 cases (44 %) were GI bleedings, with small bowel being the most common location (24 cases, Table 1). The remaining bleeding were extraluminal, with retroperitoneal (23 cases) and abdominal bleeding outside the organs (10 cases) being the most common. (Table 1).

In all cases bleeding was visible during interventional angiography. Embolization was possible in 68 cases. In 5 cases, the bleeding vessel could not be adequately reached via catheter. In 2 cases, active bleeding was identified, but no feeding vessel was visible. None of the cases had previous interventional treatments.

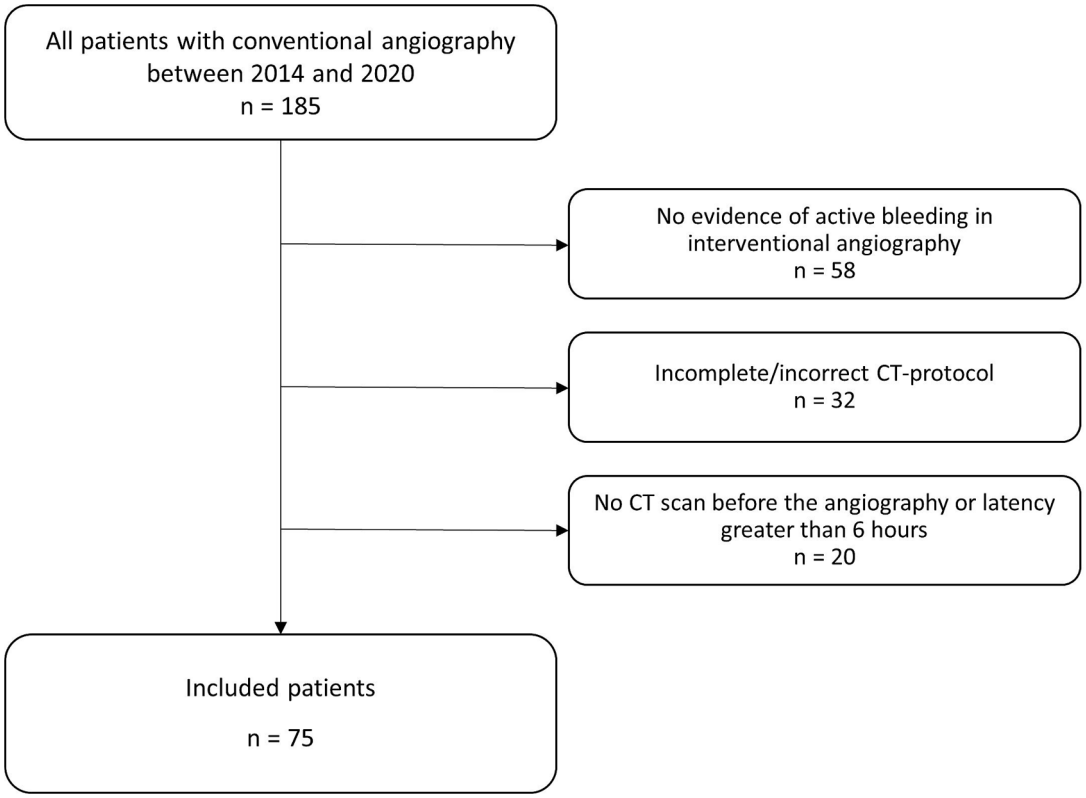

Fig. 1. Inclusion/exclusion criteria.

Table 1
Location of bleeding.

Location of bleeding	Number of cases (n)	Percentage of collective
Extra-luminal / extra-intestinal bleeding		
Retroperitoneum	23	30,7
Bleeding outside the abdominal organs	10	13,3
Abdominal wall	5	6,7
Pelvis	3	4,0
Spleen	1	1,3
Intra-luminal / intra-intestinal bleeding		
Small bowel	24	32,0
Colon	5	6,7
Stomach	2	2,7
Esophagus	2	2,7

Mean dose length product was 927.9 mGy*cm (SD 495.2 mGy*cm) for non-contrast, 631.3 mGy*cm (SD 289.3 mGy*cm) for arterial and 915.0 mGy*cm (SD 484.6 mGy*cm) for portal venous scan (Fig. 2). The arterial phase scan had significantly lower radiation dose compared to both the non-contrast and the venous phase scan ($p < 0.001$). The non-contrast scan and the portal venous phase scan were comparable in radiation dose ($p = 0.98$).

Of all 75 cases, the readers subjectively deemed the non-contrast scan to be helpful in only 3 cases. All of these cases were GI-bleedings with one receiving additional oral contrast agent on the day before the CT scan as part of a small bowel follow through for suspected ileus.

Case 1 (Fig. 3**).**

71-year-old female patient with recurrent jejunal bleeding in the context of vasculitis and renewed suspicion of bleeding. The triple phase CT scan showed a small intraluminal hyperdensity in a distal jejunal loop (see white arrow), which – possibly due to movement artifacts – featured no venous pooling. Since the non-contrast scan showed no correlate, a calcification or foreign material could be excluded and a leakage of contrast media thus active bleeding could be assumed. The subsequent interventional angiography confirmed the finding. In addition, small and large bowel intraluminal hyperdensity could be identified as oral contrast (given the day before the examination as part of a small bowel follow through) as it was already present in non-contrast scan.

Case 2 (Fig. 4**).**

77-year-old male patient with an endoscopically unstoppable bleeding from a submucosal tumor of the duodenum. Triple phase CT scan showed an arterial phase hyperdensity within the horizontal part of the duodenum (see white arrow). There was no evidence of pooling in portal venous phase. The hyperdensity was not evident on non-contrast scan. Therefore contrast leakage and thus active bleeding could also be assumed in this case. The following interventional angiography confirmed the finding.

Case 3 (Fig. 5**).**

70-year-old male patient with recurrent distal jejunal bleeding renewed suspicion of bleeding. In the subsequent triple phase CT scan, a circular hyperdensity within a jejunal loop was seen both in the arterial and – in identical configuration – in the portal venous phase. The absence of this hyperdensity in the non-contrast scan made it possible to diagnose a contrast media extravasation and thus an active hemorrhage.

Case 4 (Fig. 6**).**

87-year-old patient with hemoglobin drop and left-sided abdominal pain after left kidney biopsy. Triple phase CT scan showed contrast extravasation in arterial phase scan from the renal cortex into the perirenal space along the puncture cannel, with obvious pooling in the portal venous phase scan in the sense of active arterial bleeding. Surrounding hematoma. No additional information were gained from the non-contrast scan. Secondary findings included a previously known right psoas hematoma without active bleeding.

4. Discussion

In this study we aimed to evaluate the value of non-contrast CT scans in the detection of hemorrhage. Consensus readings by two experienced observers showed that non-contrast scan was deemed unnecessary in 72 cases (96 %). In only 3 cases (4 %), non-contrast scan was deemed necessary not primarily for the detection of the hemorrhage itself but to safely exclude false positive findings such as calcifications, unspecific intraluminal gastrointestinal hyperdensities or foreign material that could mimic contrast media extravasation. Analysis of the radiation exposure data revealed, that on average, the non-contrast scan accounted for more than 37 % of the total dose length product of the examinations.

At present, there are no studies providing evidence for or against the use of the non-contrast scan in the search for bleeding and consequently no guidelines.

Our findings suggest that a non-contrast CT scan as part of routine protocol for suspected bleeding can be safely omitted in most cases without compromising confident diagnosis of hemorrhage. Omission of the non-contrast scan results in a notable reduction of radiation exposure, which is therefore particularly desirable for young patients. However, it is important to acknowledge that in some cases non-contrast scan can be helpful, especially in suspected GI bleeding or if oral contrast has been applied. Optionally, non-contrast scan could be helpful in the

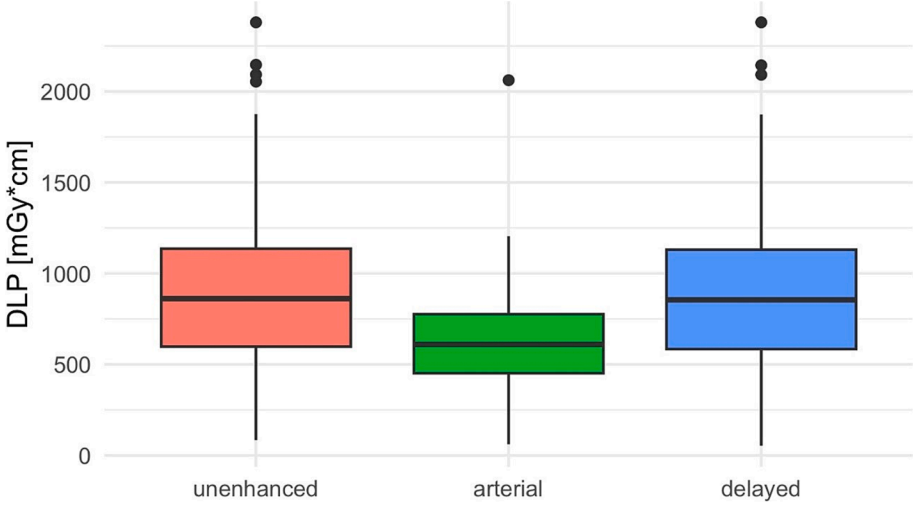

Fig. 2. Radiation exposure.

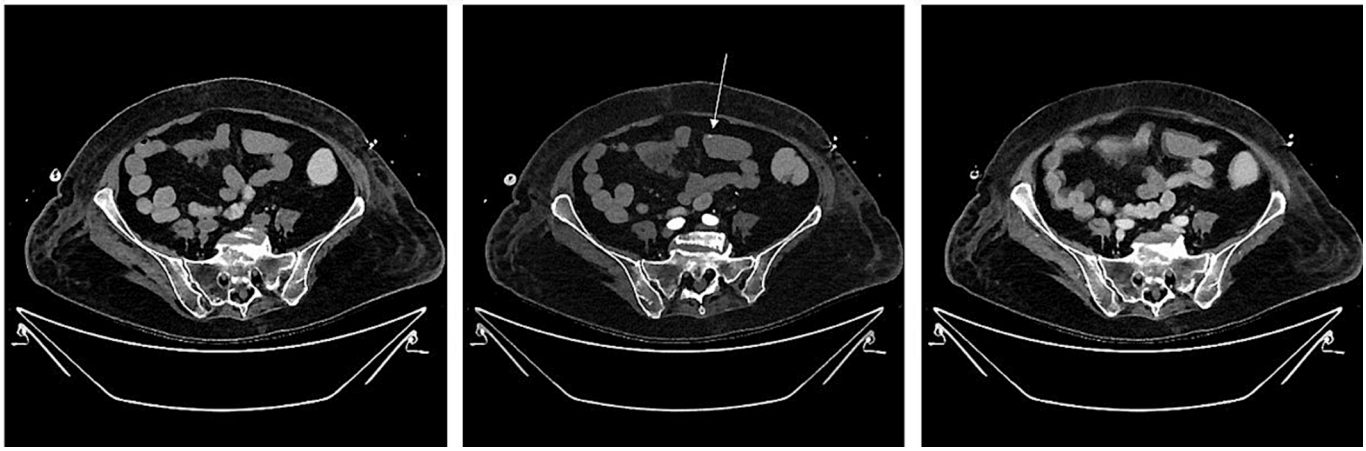

Fig. 3. Case 1: Axial slice from a CT of the lower abdomen in non-contrast (left image), arterial (middle image) and portal venous phase (right image). Non-contrast scan was assessed as helpful to safely identify the arterial phase hyperdensity in a distal jejunal loop (white arrow) without venous pooling as contrast extravasation, as it was not present in the non-contrast scan.

Fig. 4. Case 2: Axial slice from a CT of the middle abdomen in non-contrast (left image), arterial phase (middle image) and portal venous phase (right image). Non-contrast scan was assessed as helpful to be able to reliably evaluate the intraluminal arterial phase hyperdensity (white arrow) in the horizontal part of the duodenum, that showed no venous pooling, as contrast extravasation, as it was not present in the non-contrast scan.

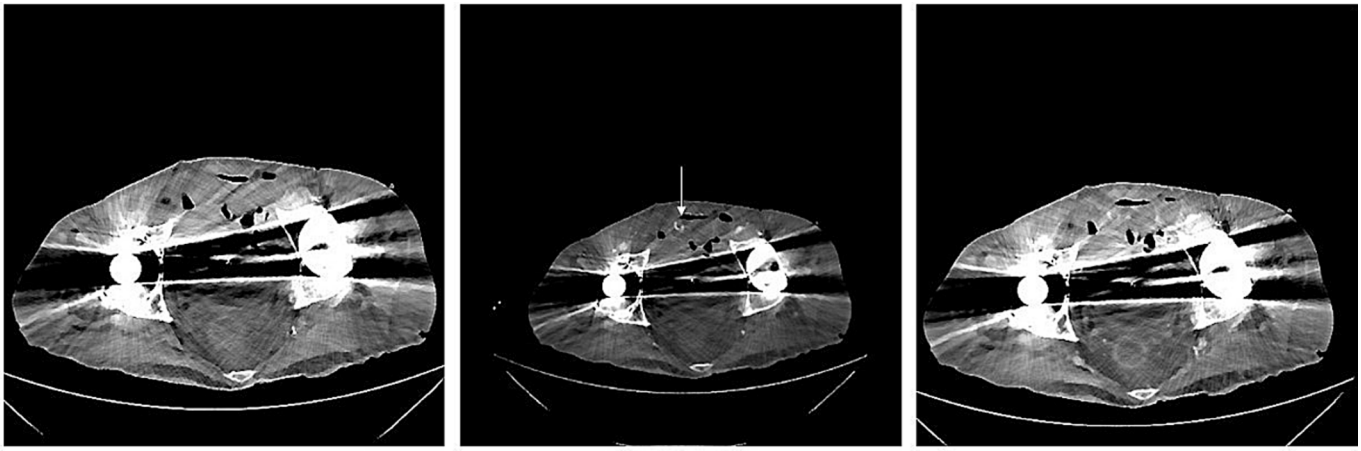

Fig. 5. Case 3: Axial slice from a CT of the pelvis in non-contrast (left image), arterial phase (middle image) and portal venous phase (right image). Non-contrast scan was assessed as helpful to be able to reliably evaluate the intraluminal arterial phase hyperdensity (white arrow) in a distal jejunal loop, that showed no venous pooling, as contrast extravasation, as it was not present in the non-contrast scan.

Fig. 6. Case 4: Axial slice from a CT of the abdomen in non-contrast (left image), arterial phase (middle image) and portal venous phase (right image). No additional information was gained from non-contrast scan, as arterial phase scan showed a contrast extravasation from the renal cortex into the perirenal space, with obvious pooling in the portal venous phase scan in the sense of active arterial bleeding.

case of foreign material or bone fragments at the suspected bleeding site. Therefore, ultimately the decision on the exact examination protocol is always the responsibility of the radiologist in charge and should be based on the patient's medical history, its age and the clinical question.

Limitations of this study are the retrospective design and the moderate number of patients. Selection bias could result from the inclusion of only cases with confirmed bleeding in interventional angiography. At the same time, it must be borne in mind that all patients included in the study underwent both CTA and conventional angiography with evidence of bleeding to ensure that every bleeding diagnosed on CT was a true and clinically significant finding. Furthermore, the examination of trauma cases with dislocated fractures and suspected bleeding could be interesting, as a non-contrast scan is often used in routine to distinguish between bone fragments and contrast medium.

Consideration of the specific clinical context, patient history, and the nature of the suspected bleeding when deciding whether to include or omit a non-contrast scan in the protocol is recommended.

In the future, the increasing spread of spectral computed tomography with the possibility of virtual non-contrast reconstruction (VNC) could provide an additional option to safely omit the (real) non-contrast scan. Initial studies have already shown the benefits of VNC in the detection of hemorrhage [9].

Key points.

Question

Does non-contrast scan add significant value in detecting hemorrhage, and is its routine use justified given the associated radiation exposure?

Findings.

Non-contrast CT was helpful in detecting hemorrhage in only 5.2 % of cases, primarily in GI bleeding, while contributing significantly to overall radiation exposure.

Clinical Relevance.

In most cases routine use of non-contrast CT scans is unnecessary for hemorrhage detection, but substantially contributes to radiation exposure. Selective use of non-contrast scans, particularly in suspected GI bleeding, can reduce false positives.

CRediT authorship contribution statement

Johannes Bremm: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Jörn Henze:** Investigation, Methodology, Writing – original draft. **Thomas Dratsch:** Investigation, Visualization. **Roman Kloeckner:** Supervision, Writing – review & editing. **David Maintz:** Supervision, Writing – review & editing. **Daniel Pinto dos Santos:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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