ECG-gated chest CT angiography: value for atypical chest pain evaluation

G Bierry (1), C Roy (1), X Buy (1), F Kellner (2), H Jlassi (1) and A Gangi (1)

In the emergency room, triage and orientation of patients with chest pain is often difficult. If the diagnosis of typical chest pain for a coronary syndrome (oppressive retrosternal pain, ECG modifications, increased myocardial enzymes) is often easy, management of atypical chest pain is more difficult. The possible differential diagnoses may be cardiac, vascular, pulmonary, pleuro-parietal as well as abdominal, gastrointestinal or musculoskeletal (injury, disease, lesions) (1, 2).

Computed tomography is a tool which has been the subject of intensive study and development for the diagnostic management of patients with atypical chest pain. CT angiography of the pulmonary arteries is well known as a reference examination for pulmonary embolisms, and is used in routine practice. During this examination, aortic injury such as dissection can be simultaneously identified or excluded. At the same time, exploration of the coronary arteries by multidetector CT Scan can now be reliably performed, and is possible in routine practice. With the development of 64-row or more multidetector systems, ECG-gated whole chest CT angiography can be performed in one breath hold (3). Existing protocols of retrospective ECG-gated CT Angiography make it possible to simultaneously explore the pulmonary arteries, the aorta and the coronary arteries. With these protocols, the potentially fatal causes of chest pain can be excluded in one single examination (4-6).

Examination of patients with chest pain is usually an emergency examination, often at night. In numerous centers the first radiology report of examinations performed at night is drafted by the resident on duty. These residents often have a heavy
ECG-gated chest CT angiography: value for atypical chest pain evaluation

workload. Thus any new diagnostic tool in the emergency room should be able to be performed and interpreted as easily as possible by residents and senior radiologists alike, within an acceptable amount of time.

The purpose of this study was to assess whether the protocol of ECG-gated whole chest CT angiography could be offered as a routine examination for the emergency management of patients with non-specific chest pain. Therefore, we first determined the interpretability of the coronary arteries, the pulmonary arteries and the myocardium using an ECG-gated CT angiography protocol, and we then compared the evaluation of lesions and interpretation time between the resident and senior radiologists.

Material and methods

Patient selection

This study prospectively evaluated computed tomography results in patients presenting in our center for evaluation of atypical chest pain over a 6 month period.

Inclusion criteria: age over 55 years old, absence of typical clinical symptoms of acute coronary syndrome (oppressive retrosternal pain, radiating into the jaw or the arm), absence of ECG signs suggesting acute coronary syndrome, normal cardiac enzyme activity. Patients presenting with clinical manifestations, ECG or biological signs suggesting acute coronary syndrome were hospitalized for medical management and emergency angiography. Patients presenting with a contraindication to the injection of an iodated contrast medium (vascular and parenchymatous). To analyse the coronary arteries, the images were reconstructed from the aortic arch to the pulmonary arteries and the myocardium. The S1 and S2 evaluations were compared and the interobserver agreement was determined. The interpretability and the morphology of the different structures mentioned above were then decided by consensus agreement of S1 and S2. This consensus interpretation (S) was compared to the interpretation of R and the agreement was calculated. The interpretability was defined as the ability to analyse a given structure correctly and confidently.

The lateral branches (segments 4, 9, 10, 12 and 14) of the coronary arteries were not included in the analysis because of they were generally small and the origins varied. Thus, 10 segments were evaluated per patient.

The observers had to determine the number of segments that could be analysed; a coronary artery was considered analysable if the entire length was visible and if the entire lumen could be studied. The morphology of the myocardium was analysed and the presence of hypodense areas was noted if present. Myocardial function (kinetic analysis and ejection fraction EF) were evaluated in the different reconstructions from 0 to 90 % of the cardiac cycle. Possible zones (lateral, septal, apical, anterior, inferior) with kinetic abnormalities were noted. The pulmonary arteries were analysed up to the sub-segmental level. Pulmonary embolisms were considered to be present when a filling defect was identified in the arterial lumen. The aorta was evaluated as atheromatous or normal, the presence of dissection was noted if present. The interpretation time for each observer was reported directly on the evaluation sheet, based on a clock in the reading station.

Statistical analysis

The statistical analysis was performed with version 11 of SPSS software (SPSS Inc, 2005, USA). The interobserver agreement concerning interpretability and lesions was calculated by determining the kappa for each analysed structure (pulmonary arteries, coronary arteries, myocardium). Interpretation time was compared between observers by the t-test. A P value > 0.05 was considered for rejection.

CT Scan examinations

Acquisition parameters

Examinations were performed with 64-row computed tomography unit (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan). The protocol included images of the full chest in the craniocaudal direction with retrospective ECG-gating, with the patient breathing normally. The acquisition parameters were: 64 × 0.6 collimation, rotation time 0.4 sec, pitch between 0.25 and 0.3; 120 kV; 200 mAs. The acquisition was performed with an automatic dose adaptor depending upon the morphology of the patient (SureExposure, Toshiba Medical Systems, Tokyo, Japan). Moreover, ECG-controlled tube current modulation was systematically applied (7). It has been shown that this protocol provides satisfactory analysis of the coronary arteries with less radiation than conventional coronary angiography (8).

Injection protocol

A triphasic injection protocol of 100 ml of iodated contrast medium (Iomeron® 400, Bracco-Altana, Le Mée sur Seine, France; 75 ml at 5 ml/s then 25 ml at 3 ml/s) was administered, followed by a bolus of saline solution 50 ml at 3 ml/s. An automatic bolus tracking program was applied for the contrast medium with a region of interest centered on the ascending thoracic aorta (threshold 150 HU).

Image reconstruction

Several different reconstructions were obtained. The first was the image of the whole chest from the diaphragm to the apex with a similar field of view to conventional pulmonary CT angiography, a slice thickness of 1mm and 0.6 mm increments, with two different specific reconstruction filters (vascular and parenchymatous). To analyse the coronary arteries, the images were reconstructed from the aortic arch to the cardiac apex with a slice thickness of 0.6 mm and increments of 0.4 mm with a field of view limited to the heart by an appropriate reconstruction filter. Different reconstructions were obtained from 0 to 90 % of the R-R interval at 10 % increments, to determine the optimal phase to analyse the different coronary arteries and for functional analysis of the myocardium.

Analysis of images

Three observers independently analysed the different reconstruction phases: two senior radiologists (S1 and S2) and a 5th year resident (R) who had experience in theoretical but not practical cardiac imaging. The interpretations were performed on a Vitrea® (Vital, Minnesota, USA) console. The observers were asked to evaluate the interpretability of the structures and to identify any lesions in the coronary artery, the pulmonary artery, the myocardium and the pulmonary parenchyma. The S1 and S2 evaluations were compared and the interobserver agreement was determined. The interpretability and the morphology of the different structures mentioned above were then decided by consensus agreement of S1 and S2. This consensus interpretation (S) was compared to the interpretation of R and the agreement was calculated. The interpretability was defined as the ability to analyse a given structure correctly and confidently.

The lateral branches (segments 4, 9, 10, 12 and 14) of the coronary arteries were not included in the analysis because of they were generally small and the origins varied. Thus, 10 segments were evaluated per patient.

The observers had to determine the number of segments that could be analysed; a coronary artery was considered analysable if the entire length was visible and if the entire lumen could be studied. The morphology of the myocardium was analysed and the presence of hypodense areas was noted if present. Myocardial function (kinetic analysis and ejection fraction EF) were evaluated in the different reconstructions from 0 to 90 % of the cardiac cycle. Possible zones (lateral, septal, apical, anterior, inferior) with kinetic abnormalities were noted. The pulmonary arteries were analysed up to the sub-segmental level. Pulmonary embolisms were considered to be present when a filling defect was identified in the arterial lumen. The aorta was evaluated as atheromatous or normal, the presence of dissection was noted if present. The interpretation time for each observer was reported directly on the evaluation sheet, based on a clock in the reading station.
Results

Patient characteristics

Thirty patients (16 men, 14 women) an average of 69 ± 10 years old were included. The average heart rate was 81 ± 18 bpm.

Pulmonary arteries

A final diagnosis of pulmonary embolism was made in 5 patients (pulmonary trunk in 2 patients, segmental in 3 patients) (fig. 1). The pulmonary arteries were considered analysable in 97 % of patients. The interobserver agreement for interpretability was 1 between S1 and S2 as well as between S and R. The interobserver agreement on the presence of pulmonary embolisms was 0.93 between S1 and S2, and 0.86 between S and R.

Coronary arteries

Atheromatous lesions were observed in 11 patients and a diagnosis of stenotic lesions or occlusion was made in 5 patients (fig. 2, 3 and 5). The coronary segments were considered analysable in 81 ± 14 % of the cases corresponding to 8.1 segments per patient. The interobserver agreement for interpretability was 0.84 between S1 and S2, and 0.76 between S and R. The interobserver agreement for lesions was 0.89 between S1 and S2, and 0.76 between S and R. There was disagreement for 23 segments between senior observers (3 segments considered normal, 18 calcifications, 12 mixed plaques) and for 72 segments between the seniors and the resident (35 segments considered normal, 17 calcified plaques, 18 non-calcified plaques, 2 mixed plaques).

Myocardium

The myocardium could be analysed in 90 % of patients. The interobserver agreement for interpretability was 1 between S1 and S2 and 1 between S and R. A kinetic segmental anomaly was diagnosed in 9 patients: segmental or global hypokinesia in 6 patients, paradoxical interventricular septal motion in 3 patients presenting with massive pulmonary embolisms. The interobserver agreement for kinetic anomalies was 0.87 between S1 and S2, and 0.87 between S and R. The myocardium was abnormally dense (focal hypodensity) in 5 patients (fig. 3). The interobserver agreement for myocardial density anomalies was 0.93 between S1 and S2, and 0.90 between S and R.
The average EF was 55% (10-70%); there was no statistically significant difference among the different evaluations (p = 0.2, t-test).

**Aorta**

The aorta was considered analysable in all patients with an agreement of 1 among the different observers. Aortic anomalies were observed in 13 patients: diffuse atheroma in 12, type B aortic dissection in 1 patient (fig. 6). The interobserver agreement for lesions was 0.97 between S1 and S2, and 0.93 between S and R (1 in all cases for the dissection).

**Non-vascular lesions**

A non cardiovascular origin for chest pain was diagnosed in 6 patients: pneumopathies (4), pleural effusion (1) and hiatal hernia (1).

**Interpretation time**

The average interpretation time was 14 and 15 minutes respectively for the resident and the senior radiologists, with no significant difference (p = 0.1, t-test).

**Discussion**

The management of patients presenting with acute chest pain is based on the de-
tection and early treatment of potentially fatal emergencies, such as acute coronary syndromes (myocardial infarction, unstable angina), aortic dissection or pulmonary embolisms. In patients presenting with acute chest pain, the source of the pain is reported to be cardiac one third of the time (9). Rapid triage is therefore essential because prognosis in these patients is correlated to the rapidity of diagnosis and management of acute coronary syndromes (2). The triage of patients with an acute coronary syndrome and chest pain from other causes is generally based on an estimation of risk derived from clinical data (age, sex, the presence of risk factors), electrocardiograms, and biological tests (10). However, the predictive value of these criteria is limited resulting in a relatively high rate of undiagnosed coronary syndromes (9, 11, 12). The incapacity to correctly identify the origin of the chest pain results in a high rate of unjustified hospitalizations, with the number of potentially useless days of hospitalisation estimated to be between 5 and more than 20 per 100 patients (13).

A rapid evaluation of the coronary arteries by CT scan could improve emergency management of patients presenting with chest pain. Coronary CT angiography is known to be a sensitive test with a high negative predictive value and it is interesting to note that approximately 40% of conventional angiographies are performed for diagnostic purposes to identify atheromatous plaques (14, 15). In approximately half the cases, chest pain is extra-cardiac. Some of these patients require rapid care (aortic dissection, pulmonary embolism) (1, 16). Chest CT angiography which is the imaging method of choice for the diagnosis of pulmonary embolisms and aortic dissection, may also identify potentially painful non-vascular anomalies such as pneumothorax, pneumopathy, or hiatal hernias.

Because coronary CT angiography can be used to exclude coronary anomalies, ECG-gated chest CT angiography has been proposed to simultaneously exclude the three main vascular causes of potentially fatal chest pain. Several clinical studies have been reported, and have shown that analysis of the aorta, the pulmonary arteries and the coronary arteries was possible (4, 6).

Nevertheless, the value of these procedures as a routine tool needs to be determined. We evaluated the interobserver agreement between senior and junior radiologists to show the feasibility of an ECG-gated CT angiography protocol in routine practice. The agreement between senior radiologists for analysis of coronary arteries was 0.84 for interpretability and 0.89 for lesions. This shows that the protocol could even be applied to patients with a rapid heart rate (81 bpm) without the use of betablockers. Most reported studies have excluded patients with a rapid heart rate or patients with a contraindication to betablockers (17). In routine practice, patients presenting with chest pain often have tachycardia and information about possible contraindications to betablockers are difficult to obtain in the emergency setting.

The agreement for analysis of coronary arteries was 0.76 between senior and junior radiologists. This shows that a resident can perform a satisfactory evaluation of the coronary arteries using an ECG-gated chest CT angiography protocol. The presence of pulmonary embolisms was identified in 5 patients (17% of all patients). These results are similar to those in the literature with a rate of embolisms of approximately 18% detected in patients presenting with chest pain (4). The interobserver agreement for the diagnosis of pulmonary embolisms was excellent and comparable to the results in the literature (18).

Analysis of the myocardium can provide additional indirect information about the origin or severity of the pain-causing lesions. Sub-endocardial hypoperfusion of the myocardium was observed in 5 patients, suggesting myocardial ischemia. In 6 patients, diffuse or focal hypokinesia
with a reduced ejection fraction (EF) was identified on functional analysis. Three patients presented with simultaneous coronary lesions and an ischemic origin was identified as the cause of the chest pain. In three patients with a pulmonary embolism analysis of myocardial kinetics showed paradoxical interventricular septal motion, indicating cardiac overload which is a well know factor of a poor prognosis (19). The interobserver agreement for analysis of the myocardium (kinetics, morphology) was excellent, 0.93 and 0.87, respectively between senior radiologists and the resident. Moreover, no significant difference was found in the evaluation of the EF among the observers. Analysis of myocardial morphology and function can therefore be proposed in routine practice with ECG-gated chest CT angiography. The main advantage of retrospective ECG-gated synchronization is the ability to obtain functional cardiac analysis. Routine use of an emergency imaging analysis protocol should be interpretable within a minimum amount of time. The average time for interpretation was 15 minutes which was satisfactory for the observers in an emergency setting.

There are several limits to our study. First, we only evaluated the 10 major coronary segments. Assessment of all the segments could completely exclude a coronary cause of pain and thus improve the negative predictive value of the test. ECG-gated chest CT angiography should only be used as a triage tool to rapidly exclude any major anomaly of the coronary network. Thus it should not be compared to coronary CT angiography. The ability of this examination to conclusively identify coronary damage is limited, and its main purpose is to suggest a diagnosis. Although we evaluated the quality of CT scan images for analysing coronary arteries, we could not compare them to conventional angioigraphy. Thus the precision of our results could not be confirmed, and there may have been false negatives. We tried to compensate for this by obtaining a consensus between senior radiologists for the final diagnosis. Finally, we did not compare interpretation time between our protocol and conventional chest CT angiography. Interpretation of ECG-gated chest CT angiography is probably longer, but may, on the other hand, reduce the overall examination time for the patient.

The final limit of ECG-gated chest CT angiography is radiation. Although gated protocols are known to produce more radiation, several studies have shown that a satisfactory assessment of coronary arteries is possible with a lower DLP than traditional coronary CT angiography using dose modulations and low amperage (8, 20, 21).

**Conclusion**

ECG-gated chest CT Angiography appears to be an interesting tool for exploring atypical chest pain in the emergency setting because all the vital thoracic structures can be analysed in a single examination, including the coronary arteries, the pulmonary arteries and the aorta. ECG-gating provides complete assessment of the myocardium, which can provide additional, useful diagnostic information. The very good interobserver agreement shows that this type of examination can be performed by residents as well as senior radiologists. Finally, the time necessary for interpretation is acceptable, allowing its use as a routine protocol to evaluate patients presenting with chest pain in the emergency setting.

**References**

