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Multi-slice computed tomography in the diagnosis of pulmonary embolism – usefulness of multiplanar reformations with batch film tool in the form of a paddle view

Pulmonary embolism (PE) is a common and still difficult clinical problem. In the USA, almost half a million cases of PE are documented annually (4). In Poland, there are still no equally reliable, fully documented data concerning the incidence of this disease. The clinical experience of the authors shows that PE occurs proportionally with similar frequency. PE is diagnosed in 15–25% of hospital deaths on autopsy, yet only 1/3 of the diagnoses are established intravitally (3,5,11). An early diagnosis and antithrombotic treatment reduces the mortality rate from 30 to 2–10% (2). Due to such poor diagnostic results achieved so far, the use of methods enabling substantial improvement in the field becomes a vital issue. The clinical diagnosis of PE is usually based on the evaluation of signs detected in patients, determination of D-dimer levels and imaging methods, of which the chest X-ray, ventilation-perfusion (V/Q) lung scans and pulmonary angiography were already used before 1990s. For many years, the first two methods, although lacking satisfactory effectiveness rates, were a gold standard; in some cases supplemented with an invasive method of contrasting the pulmonary vessels. In the Polish centres, even the clinical ones, a quick, full diagnosis of PE was often extremely difficult to reach.

Incremental computed tomography did not play a relevant role in the diagnosis of PE although the first case was already described by Sinner in 1978 (12). The reasons included: too long rotation time, thickness of slices which did not allow to evaluate the thrombotic material in the segmental vessels and lack of possibilities to perform reliable secondary reconstructions of arteries. New possibilities were created when spiral tomographs were introduced, which provided the acquisition of volume data. Single-slice CT facilitated detection and evaluation of thrombotic lesions in the central vessels up to the segmental ones during a single breathhold, which, depending on the rotation time, lasted from 12.5 to 25s.(6,2). The results concerning the evaluation of vessels of smaller caliber were unsatisfactory and the post-contrast scanning time with a single breathhold was often too long for dyspnoeic patients.

MSCT introduced for the first time in 1998 substantially shortened the scanning time (even to 4–5s) in the protocols used in patients with severe dyspnoea or in uncooperative individuals (7). The purpose of the study is to show the dagnostic possibilities of pulmonary multi-slice computed tomography angiography (MSCTA) and to present our own experiences

concerning the examination protocol as well as the way of performing and evaluating multiplanar reconstructions (MPR) according to the two diagnostic algorithms used by us.

MATERIAL AND METHODS

Between July 2002 and February 2003, 62 patients (35 women and 27 men, aged 18–80, average 59) suspected of having PE were subjected to pulmonary multi-slice computed tomography angiography (MSCTA). Thirty six patients were referred to CT as urgent cases, the remaining patients showed pulmonary hypertension symptoms and clinical features of recurrent pulmonary embolism. The D-dimer levels were earlier determined in all of the patients. Thirteen patients underwent ventilation-perfusion scintigraphy and one was subjected to pulmonary artery angiography.

MSCT angiography. The CT examinations were performed with 8-row LIGHTSPEED ULTRA (GE) tomograph using the following parameters: the examined area – from the level of the phrenic dome to the lung apices in the pre-contrast scanning with the slice thickness of 5mm and post-contrast scanning with 8x1.25mm collimation, 50% overlapping and 13.5mm/s table feed. In the patients with severe dyspnoea, the 27mm/s table feed and secondary 1.25mm slice reconstructions were used. The patients with chronic pulmonary hypertension were additionally subjected to standard HR scanning. The contrast medium (Ultravist 300 and 370 and Visipaque 300) in the amount of 100–120ml was injected with the automatic power injector (Medrad) and speed of 4ml/s. The scanning delay was determined in 12 cases on the basis of the test bolus and in the remaining ones on the basis of density measurements in the pulmonary trunk using the Smart Prep technique. The scanning time during CT angiography with 1.25mm collimation was 10-14s and 350–480 axial native scans were obtained. In the dyspnoeic patients the breathhold was shortened to 5–5.8s at 2.5mm collimation, if required. Postprocessing was performed using the Adventage 4.0 workstation (GE). In each patient, the native scans and multiplanar reformation (MPR) images in axial, sagittal and coronal projections using render mode maximum intensity projection (MIP) 3.6–5.9 were performed and visualization of the pulmonary artery branches and thromboembolic material was assessed. Then the reconstructions with batch film tool in the form of a paddle view with the rotation axis located at the site of the left pulmonary artery ostium were performed and 179 images were obtained with every 1° rotation starting from the line of the interlobar fissure of the left lung with the parameters: width of window – 650HU, center – 70HU, slice thickness – 3.6, MIP – 4.5–8.6.

The incidence and localization of PE were analyzed and the pulmonary artery visualization in typical MPR projections was assessed. Moreover, applications of the paddle view in the individual pulmonary lobes according to the vessel size (i.e. lobar, segmental and subsegmental branches) were evaluated. The direct criteria of acute PE by Sinner (12,13) and of chronic PE by Schwickert (8,9) were accepted as the CT signs enabling the detection and determination of the character of PE. Moreover, the indirect signs were employed concerning the changes in the lung parenchyma (ancillary findings), heart and vessel beds described by Teigen et al. (15), Tardivon et al. (14) and Shah et al. (10). The scale used to assess the difficulties in evaluating the course and lumen of the arteries for detecting the embolic material ranged from 0 to 3 (0 – lack of evaluation possibilities, 1 – very difficult evaluation, indeterminate, 2 – good visualization and possibilities of analyzing the vessel course, 3 – excellent visualization with possible evaluation of the embolic material location in relation to the artery wall).

The scans were reviewed by 3 independent radiologists who determined interobserver consensus. The results were compared with those evaluating native scans and MPR in three perpendicular planes as well as those of the batch film tool evaluation. The statistical analysis was conducted using the Mann-Whitney test (Statistica 6.0). A p value<0.05 was considered significant.

RESULTS

The thromboembolic material in the pulmonary arteries was visualized in 35 out of 62 MSCT examinations; in 20 cases the lesions fulfilling the criteria of acute PE dominated. In one patient the image was inconclusive due to artifacts. Four patients had only the indirect signs of chronic, recurrent embolism. In 17 examinations (including 6 with PE) some other types of lesions were observed, e.g. inflammatory-infiltrative changes, neoplastic lesions, abnormal venous flow, myxoma of the left atrium, bronchiolitis obliterans, fibrosis interstitialis. 21 out of 25 patients in whom the comparative analysis concerning the two protocols of PE evaluation with multiformat reconstructions was performed showed the features of bilateral embolism, in 9 the lesions affected all the lobes and only in 5 were confined to one lobe. The symptoms of central embolism were dominant in 7 patients and of peripheral embolism in 4. The majority of patients had mixed lesions. In all the arteries examined, the mean index for MPR in 3 perpendicular projections was 2.24 while with the batch film tool – 2.47 ($p<0.05$). The use of only one or both methods did not affect the diagnosis of pulmonary embolism and the differences observed were only quantitative.

In multiplanar reformation evaluation (sagittal, coronal and axial scans), the following mean values were obtained: 2.92 – main arteries, 2.68 – lobar arteries, 2.12 – segmental arteries and 1.68 – subsegmental ones. With an additional paddle view, the mean values were as follows: 2.96, 2.78, 2.35 and 2.08, respectively. The differences in both groups were significant in the cases of segmental and subsegmental branches.

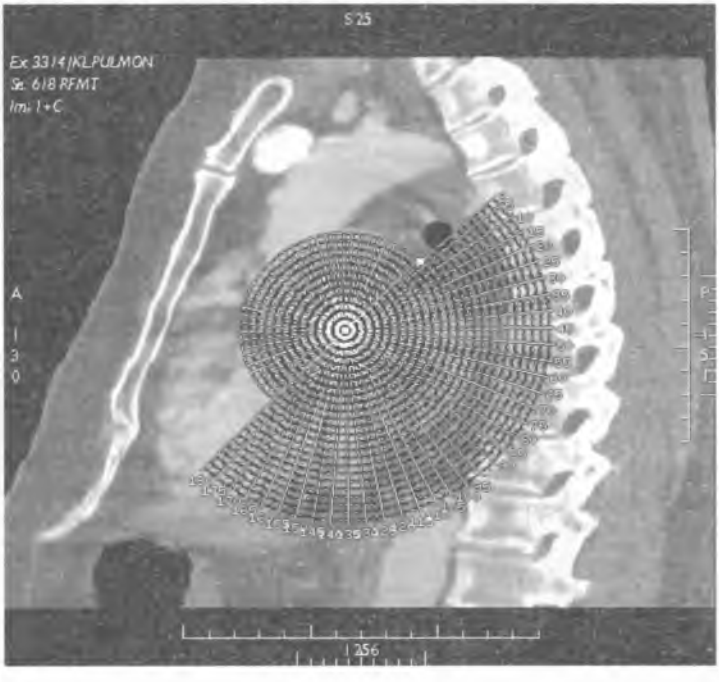
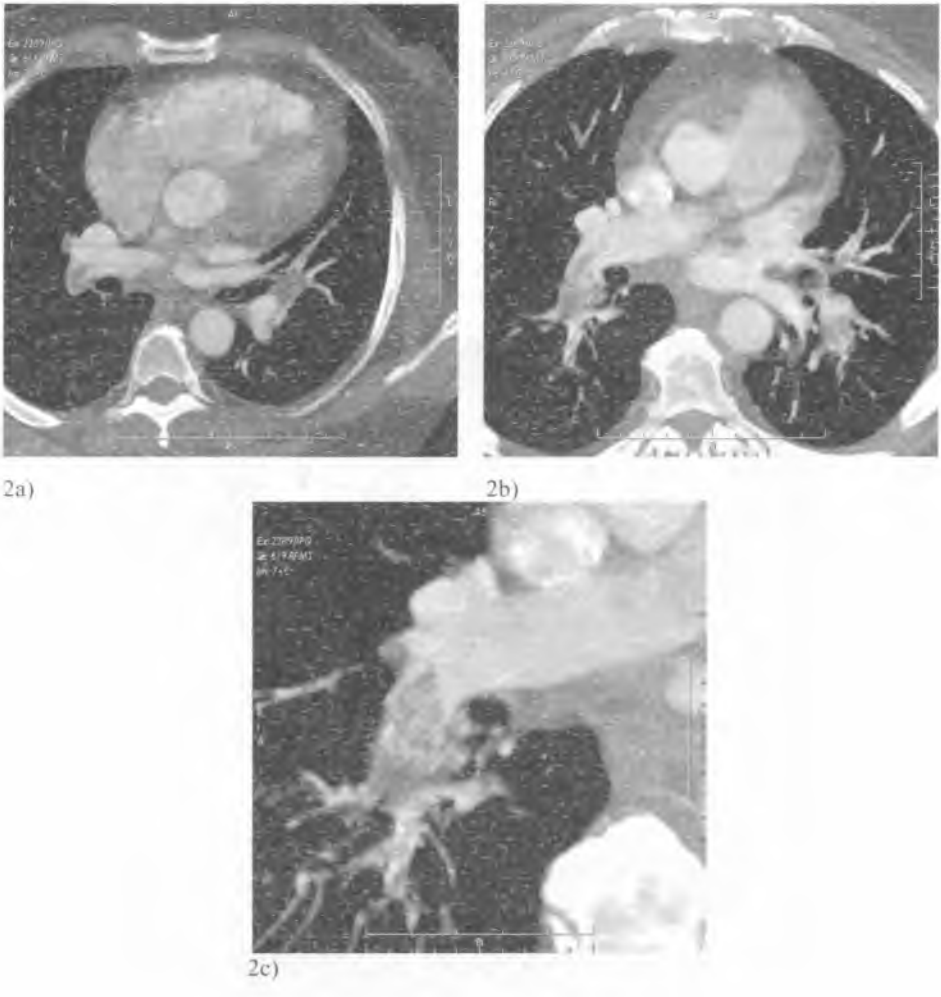


Fig.1. Batch film mode in the form of paddle view – topogram

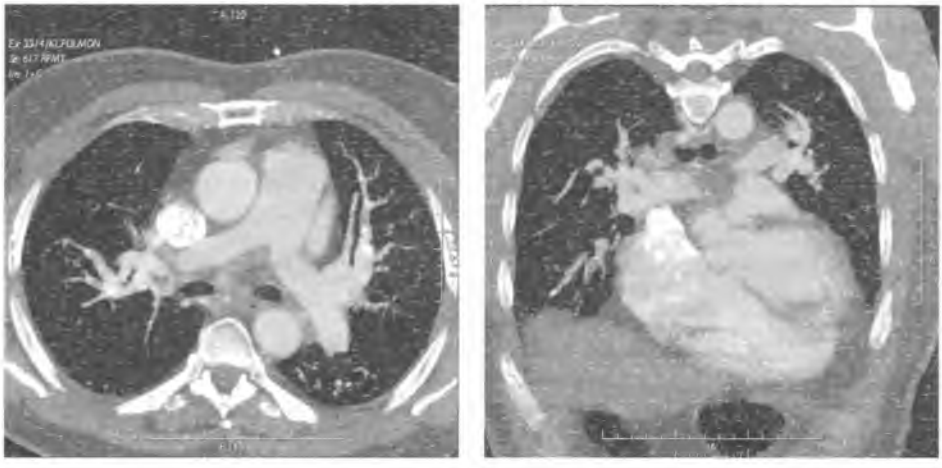
The lowest total index was found on MPR evaluation of the right medium lobe arteries (1.92) and the highest one was observed for the right inferior lobe (2.31). The indices for lobar arteries were 2.58–2.75, for segmental arteries – 1.83–2.33 and for subsegmental ones – 2.33-

2.00.With the batch film tool all the mean indices were higher, being 2.17–2.58 for segmental branches and 1.92–2.25 for subsegmental ones. Analogously to significantly different results for peripheral arteries obtained in typical and widened (BFT) evaluation of PE, the radiologists-observers explicitly agreed that the use of the batch film tool for evaluation of embolism of peripheral pulmonary arteries enabled better visualization of the course of segmental and subsegmental arteries, the sites of their division and anatomical variants. Moreover, it allows to observing long parts of vessels according to their natural anatomical distribution and provides a convenient form of data filing for clinical use. The evaluation time while using both methods increased on average by about 5 minutes.



2a) 2b) 2c)

Fig. 2. Patient G.I., female, 47 years old, with symptoms and signs of acute pulmonary embolism. Fragments of embolic material in pulmonary artery: a) MPR axial reconstruction in maximum intensity projection shows the thrombi creating acute angle with the artery walls, b) greater number of segmental and subsegmental branches are visible with the use of a batch film mode, c) enlarged picture demonstrates partially occluded segmental and subsegmental branches



a) b)

Fig. 3. Patient K.S., male, 62 years old, with symptoms of aggravating chronic dyspnoea. In the site of pulmonary trunk division a large embolic material is visible, but segmental and subsegmental branches are not totally occluded (a). Embolic material is visible along left pulmonary artery in BFT mode (b) – chronic PE

DISCUSSION

The results of visualization of the course and lumen of the pulmonary arteries obtained in this study accompanied by the evaluation concerning the presence of the embolic material and morphological changes differentiating acute and chronic PE are consistent with the findings of other authors and demonstrate a high value of MSCTA (1,2,6,7). According to the accepted scale, all the indices exceeded 2.0, which shows that radiologists highly appraise the routine use of multiformat reconstructions with maximum intensity render mode in the diagnosis as well as quantitative and qualitative evaluation of the lesions observed in PE. Moreover, the studies proved the usefulness of additional secondary oblique reconstructions around the rotation axis accepted (BFT). Substantially higher values of indices for evaluation of segmental branches and peripheral arteries demonstrate higher precision of evaluation and high value of this, partly formalized but repeatable, diagnostic method. Once some experience in assessing the anatomical relations in this projection has been gained, a relatively short time required to use this reconstructive application and possibilities to document the paddle view images in the cine form enable us to introduce it to the routine clinical practice. The lowest values were obtained in evaluation of arterial branches in the region of the lingula and right mild lobe, where the oblique course of vessels, which is unfavorable for imaging and susceptibility to cardiac artifacts, pose the biggest diagnostic problems in the PE evaluation (2). The BFT method used for this location gave positive results. Simultaneously, the paddle view method sorts the way of evaluation and interpretation of images of pulmonary vessels, determines step-by-step assessment of their successive branches eliminating the free choice of methods used by various radiologists.

CONCLUSIONS

1. 8-row MSCT angiography is a valuable method of visualization of lobar, segmental and subsegmental pulmonary arteries and of diagnosis of pulmonary embolism.

2. The additional use of batch film tool in the form of a paddle view (GE) facilitates evaluation of peripheral branches and thromboembolic material in their lumen.

3. Both evaluation methods – analysis of native scans and MPR in transverse, sagittal and coronal planes with MIP and the additional use of the batch film tool – may be applied in the detection of embolic lesions and provide similar effects.

4. Records of examinations with BFT may be a readable form of PE imaging for clinicians.

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SUMMARY

Pulmonary embolism (PE) is a common and still difficult clinical problem. On autopsy, PE is diagnosed in 15–25% of hospital deaths, intravitally the diagnosis is reached in only 1/3 of cases. An early diagnosis and antithrombotic treatment decreases the mortality rate from 30 to 2–10%. The aim of the study is to show diagnostic possibilities of pulmonary artery angiography using 8-row multislice spiral computed tomography (MSCTA) and to present our own experience concerning the examination protocol as well as the way of performing and evaluating multi-planar reconstructions (MPR). Since July 2002, 62 patients suspected of having PE were subjected to MSCTA with the LightSpeed Ultra tomograph (GE) using the Smart Prep technique with 8x1.25mm collimation, 0.6mm interval, iv 100–120ml of the contrast medium (4 ml/s) with scanning delay. The scanning time was 10–14s. In the patients with severe dyspnoea the 2.5mm slices were used (the required time of breathhold – 5–7s). The patients suspected of having chronic PE were additionally subjected to high resolution dynamic scanning. Postprocessing included the evaluation of native scans and multiplanar reconstructions using 3.6–5.9 MIP for visualization of pulmonary artery branches and thromboembolic material. The standard reconstructions were supplemented with the batch film tool (BFT) in the form of a paddle view. In 25 cases the values of typical and widened reconstruction algorithms were compared according to the caliber and location of vessels using the 0–3 scale. The thromboembolic material in the pulmonary arteries was visualized in 35 MSCTA examinations; in 20 cases the lesions fulfilling the criteria of acute PE dominated. In 1 case the image was inconclusive. 17 examinations revealed other types of lesions, e.g. inflammatory-infiltrative or neoplastic changes, abnormal venous flow, myxoma of the left atrium, bronchiolitis obliterans. The three-planar evaluation of MPR and MPR with BFT showed that the effectiveness rates were as follows: 2.92 and 2.96 for the main arteries, 2.68 and 2.78 for lobe arteries, 2.12 and 2.35 for segmental arteries ($p<0.05$), 1.68 and 2.08 for subsegmental ones ($p<0.05$), respectively. 1. MSCTA is a valuable and quick method of visualization of central and peripheral branches of pulmonary arteries and detection of the presence and character of embolic changes. 2. The additional use of the batch film tool in a paddle view facilitates anatomical evaluation of segmental and subsegmental branches and thromboembolic material in their lumen.

Tomografia wielorzędowa w diagnozowaniu zatorowości płucnej – przydatność rekonstrukcji wielopłaszczyznowych z opcją batch film tool

Zatorowość płucna (PE) jest częstym i nadal trudnym problemem klinicznym. Sekcyjnie jest rozpoznawana w 15–25% przypadków zgonów szpitalnych, przy czym tylko 1/3 rozpoznań jest stawiana przyżyciowo. Wczesne rozpoznanie i leczenie przeciwzakrzepowe zmniejsza śmiertelność z 30 do 2–10%. Celem pracy jest przedstawienie możliwości diagnostycznych angiografii tętnic płucnych przy pomocy 8-rzędowej spiralnej tomografii komputerowej (MSCTA) oraz własnych doświadczeń dotyczących protokołu badania i wykonywania oraz oceny rekonstrukcji wielopłaszczyznowych (MPR). Od lipca 2002 r. u 62 chorych z podejrzeniem PE wykonano MSCTA przy pomocy aparatu LightSpeed Ultra (GE). Stosowano kolimację 8x1,25 mm, interwał 0,6 mm, dożylne podanie 100-120 ml środka cieniującego (4ml/s) z opóźnieniem skaningu w technice SmartPrep. Czas skaningu wynosił 10-14s, przy znacznej duszności stosowano warstwy 2,5 mm (konieczny czas zatrzymania oddechu 5-7s). U chorych z podejrzeniem przewlekłej PE dodatkowo wykonywano dynamiczny skaning wysokiej roz-

dzielczości. Postprocessing obejmował ocenę skanów źródłowych oraz trójpłaszczyznowych rekonstrukcji z użyciem MIP 3,6–5,9 dla wizualizacji rozgałęzień tętnic płucnych i materiału zatorowego. Standardowe rekonstrukcje uzupełniano o obrotowe projekcje skośne w opcji cine-batch film tool (BFT). W 25 przypadkach porównano wartość typowego i rozszerzonego algorytmu rekonstrukcyjnego w zależności od kalibru i lokalizacji naczyń, stosując skalę 0–3. Materiał zatorowy w tętnicach płucnych uwidoczniono w 35 badaniach MSCTA, a w 20 przyp. dominowały zmiany spełniające kryteria ostrej PE. W jednym przypadku obraz był niejednoznaczny. W 17 badaniach stwierdzono inne typy zmian, np. zapalno-wysiękowe, nowotworowe, nieprawidłowy spływ żylny, śluzaka lewego przedsionka, *bronchiolitis obliterans*. W oparciu o ocenę MPR i MPR z BFT uzyskano wskaźniki jakości oceny tętnic głównych odpowiednio 2,92 i 2,96, płatowych 2.68 i 2,78, segmentowych 2,12 i 2,35 ($p<0,05$) oraz subsegmentowych 1,68 i 2,08 ($p<0,05$). 1. MSCTA jest wartościową i szybką metodą wizualizacji rozgałęzień centralnych i obwodowych tętnicy płucnej oraz rozpoznawania obecności i charakteru zmian zatorowych. 2. Dodatkowe zastosowanie obrotowych projekcji skośnych w opcji cine ułatwia ocenę anatomiczną gałęzi segmentowych i subsegmentowych oraz materiału zatorowego w ich świetle.