*Original Articles*

# OPTIMIZING EMERGENCY DIAGNOSTIC IMAGING IN PATIENTS WITH PULMONARY EMBOLISM IN THE EMERGENCY ROOM

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## Summary

We performed a retrospective evaluation of the criteria for suspected pulmonary embolism (PE) and requests for computed tomography angiography (CTA) by the emergency room (ER) teams. Simultaneously, we tried to find irregularities in their work. Then we designed new behavioral protocols, and yearly we evaluated the effect on the workload of the computed tomography (CT) unit of the Roentgenology and Radiology at the University Hospital – Pleven and the total impact on the behavior of the teams in cases of suspected for PE. The data from before and after the intervention was evaluated. After the implementation of the protocols, matching the criteria of PE rule-out criteria (PERC), the number of D-dimer testing, echocardiography, and computed tomography pulmonary angiographies (CTPA) was significantly higher. We found that the number of patients urgently transported for primary thrombectomy had increased, and the reduction of PE mortality in the Emergency Unit proves the safety of our intervention. Overall, the intervention in the attitude of the ER teams has a significant positive effect on the management of patients with suspected PE.
**Key words:** pulmonary embolism, PERC, CTA

## Introduction

Pulmonary embolism (PE) and deep vein thrombosis (DVT) are two of the components of thromboembolism [1, 2]. So far, science does not have a 100% credible method for diagnosing PE, because it occurs in a variety of forms, vessel changes are transitory, and the risk to accept a false negative result stays if the test is late. Besides, the interpretation of the panel of tests is difficult, because there is PE with standard test results – electrocardiography (ECG), lung x-ray and arterial blood gases (ABGs) [3-6]. Clinical data and a proven factor justify performing diagnostic imaging /spiral computed tomography (CT) with contrast, thus solving the diagnostic dilemma.

Today, spiral CT is a leading diagnostic method for finding PE [7, 8-11). This imaging test is gaining increased popularity as a non-invasive method for diagnosing PE since it has many advantages over scintigraphy [12-15]:

- The speed of the test and the possibility for direct visualization of the spiral CT with the help of the injected contrast medium CTPA [16];
- Clarification of the underlying pathological processes in the lung parenchyma [16];
- Differential diagnostic specification of other pulmonary diseases [17];
- High specificity of the results [18].

CT direct signs (as seen on Figure 1) are a definitive proof for PE. They immediately visualize the intraluminal defect – thrombus in the shape of a hypodense zone with the contrast-filled vessel in the background [7-9, 19, 20].

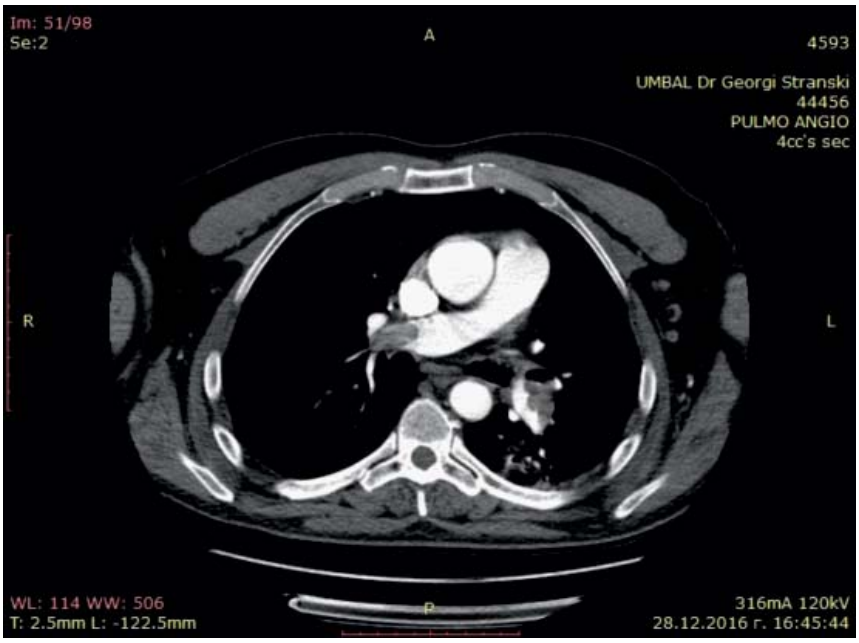


**Figure.1.** Massive pulmonary embolism, defect in the filling of the left and right branch of the PA (ER patient)

## Materials and Methods

The protocol of the current study was conducted in accordance to the Declaration of Helsinki.

The patients included in the study were: 233 162, examined in the ER at the University Hospital – Pleven, 44 276 examined in the Department of Roentgenology and Radiology, as well as patients who died in the ER, were autopsied and the pathoanatomical diagnosis was PE.

Sources of data: ambulatory sheets from the ER, autopsy protocol of the deceased, laboratory data from the information system of University Hospital – Pleven, data from the readings of the Department of Roentgenology and Radiology.

The aim of the study was to determine whether the implementation of a unified protocol for action when PE is suspected would improve the behaviour of the ER teams and how it would affect the workload of the imaging diagnostics sector.

To achieve that goal we set the following tasks:

- To conduct a retrospective study to determine the amount of patients with PE, who were examined in the ER at the University Hospital – Pleven, the imaging and laboratory tests, performed to those patients during the period 2011-2016 (before the implementation of the protocol) and to compare the data with the respective data from the period following the implementation of the protocol (2016-2017);
- To introduce the PE rule-out criteria (PERC) protocol to exclude PE, which is presented on Figure 2;
- To determine connections between the two periods, and whether the implementation of the protocols have reduced the amount of CTPA and how the protocol for behaviour with suspected PE affected mortality due to PE.

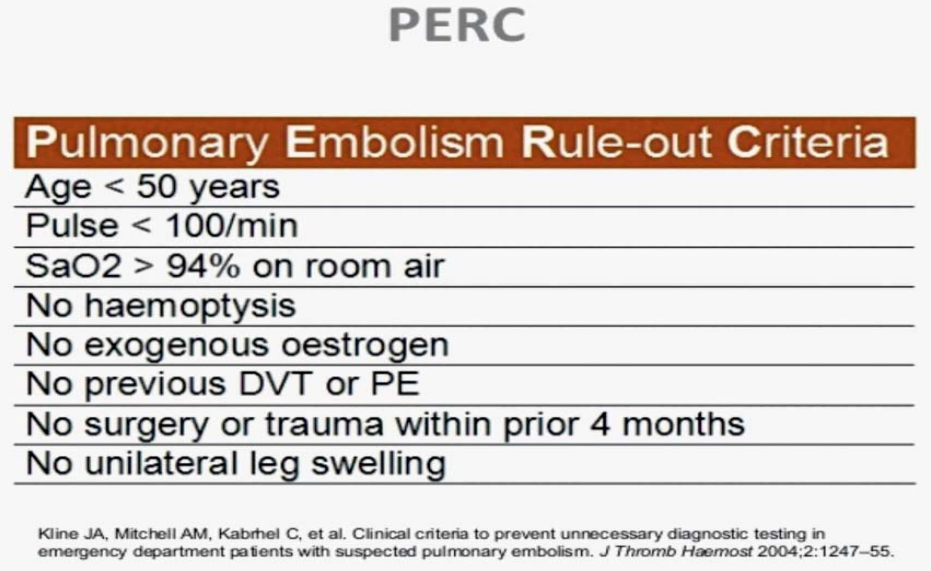


**Figure 2.** PERC-rule

## Results

Analysis of the situation before the implementation of the protocol.

During the period 2011-2015, before the behavioural protocols were implemented, 156 848 people were examined in the ER; and 256 (1.63‰) of them were diagnosed with PE (122 males and 134 females, as shown on Table 1.

Following the implementation of the behavioral protocols, 76314 people were examined in the ER, 102 of them had PE; and 69 were hospitalized. When analysing mortality by causes, the 5-year autopsy retrospective analysis of the ER – University Hospital – Pleven mortality (2016) revealed that PE is the second cause with 13.5%. However, it but remains unrecognized in over 70% of the cases (Table 2).

After implementation of the behavioural protocols, PE mortality in the ER changed significantly during the period of 2016-2017: with the same number of deaths in the ER (350 over a 5-year period and 350 for the following 2-year period), the share of the PE deaths dropped from 12.6% to 4.0%. The gender distribution remained the same (49% women, 51% men).

Between 2011 and 2015, the ER at the University Hospital – Pleven did not have a unified protocol for diagnosing and behaviour in case of a possible embolic incident. We trusted

**Table 1.** Patients, examined in the ER for the first and second period of the study

| | | Total examinations | Total PE | male | female | Hospitalized with PE | Cases of PE per 1000 |
|---|---|---|---|---|---|---|---|
| | 2011 | 25703 | 42 | 19 | 23 | 39 | 1.63 |
| | 2012 | 27630 | 54 | 22 | 32 | 43 | 1.95 |
| | 2013 | 32312 | 53 | 36 | 17 | 44 | 1.64 |
| | 2014 | 34456 | 55 | 28 | 27 | 44 | 1.6 |
| First period | 2015 | 36747 | 52 | 17 | 35 | 42 | 1.42 |
| Total for the period | | 156848 | 256 | 122 | 134 | 212 | 1.63 |
| | 2016 | 37469 | 48 | 30 | 18 | 32 | 1.28 |
| Second period | 2017 | 38845 | 54 | 33 | 21 | 37 | 1.39 |
| Total for the period | | 76314 | 102 | 63 | 39 | 69 | 1.34 |

**Table 2.** Deaths in the ER during the first and second period of the study

| Mortality in the ER | Total deaths | Deaths from PE (number) | | | Portion of PE from mortality |
|---|---|---|---|---|---|
| | | Total | male | female | |
| Mortality in the ER in first period (2011-2015) | | | | | |
| 2011 | 53 | 3 | 1 | 2 | 6 % |
| 2012 | 71 | 11 | 6 | 5 | 16 % |
| 2013 | 63 | 9 | 5 | 4 | 14 % |
| 2014 | 75 | 11 | 6 | 5 | 15 % |
| 2015 | 88 | 10 | 5 | 5 | 11 % |
| Total | 350 | 44 | 23 | 21 | 13 % |
| Mortality in the ER in second period (2016-2017) | | | | | |
| 2016 | 130 | 6 | 3 | 3 | 5 % |
| 2017 | 117 | 8 | 4 | 4 | 7 % |
| Total | 350 | 14 | 7 | 7 | 4 % |

the experience and qualifications of the doctors.

The following imaging tests were performed in the Department of Roentgenology and Radiology during both periods (Table 3).

**Table 3.** Performed imaging tests of patients with PE (hospitalized and deceased

| | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **Total** |
|---|---|---|---|---|---|---|---|---|
| Total CT scans | 2656 | 3425 | 4070 | 6560 | 7573 | 9693 | 10499 | 44476 |
| Total chest CT with contrast | 73 | 301 | 480 | 318 | 1219 | 2030 | 2375 | 6796 |
| Imaging (Echo, Ro, CT ) for care pathway PE | 45 | 79 | 82 | 110 | 142 | 141 | 279 | 878 |
| Ro | 21 | 49 | 34 | 51 | 65 | 72 | 74 | 366 |
| CT | 4 | 23 | 28 | 32 | 45 | 47 | 87 | 266 |
| Echocardiography | 20 | 7 | 20 | 27 | 32 | 22 | 31 | 159 |
| ER | 6 | 12 | 16 | 20 | 25 | 34 | 55 | 168 |
| Total pulmonary angiographies for PE | **10** | **35** | **44** | **52** | **70** | **81** | **142** | 434 |

For the first period (2011-2015), before the protocol implementation, we found out that:

- For the whole period, 24 284 CT scans were performed in the hospital, and the annual share of contrast chest scans was relatively stable – 10%;
- There was a tendency for increase in the CT requests for different cases, and chest CT with contrast in particular;
- In the beginning of the period (up to 2014), while executing care pathway for PE, more lung and heart x-rays and echocardiographies (ECGs) than CTPA were performed;
- During the following period (2016-2017) the following changes were noticed:
- The total amount of performed CT scans was 20 192 (80%) of the respective scans for the previous 5-year period, with around 18% annual increase, and the contrast chest scans were doubled – from 10 to over 22% of all CT scans;
- After 2015, the portion of CT pulmonary angiographies exceeded that of X-rays and echocardiographies, which shows that clinicians depend more on the CTPA to prove or reject the PE diagnosis, rather than on echocardiography;
- The CTPA requests by the ER were also doubled (for the first 5-year period,

there were 79 requests, while for the following 2-year period there were 89 requested and performed CT pulmonary angiographies).

Despite the increased workload of the Department of Roentgenology and Radiology, if we focus only on the ER and the PE diagnosing, a very positive tendency is noticed (Figure 3).

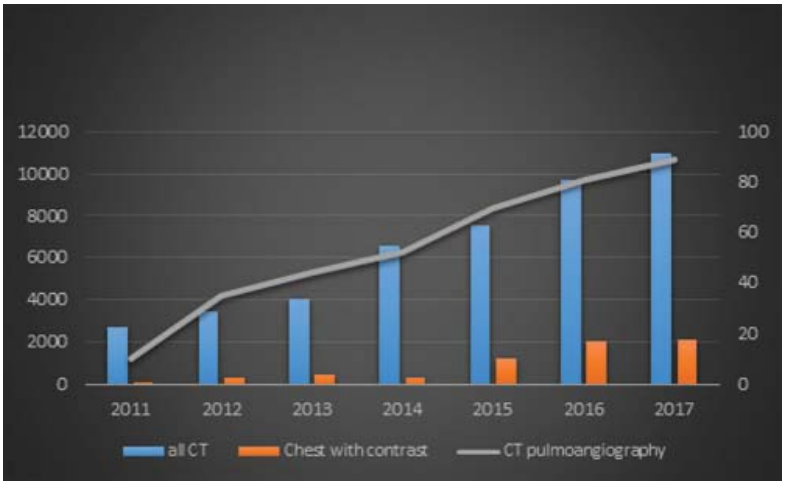


**Figure 3.** Illustrates the increase of CT pulmonary angiography requests by the ER ( n=434)

The constant increase in the ER examinations did not lead to a significant increase in the PE cases as an absolute number – they increased not only as diagnosed during examination (around 50 cases per year), but also as hospitalizations (about 40 cases per year) and deceased (approximately 10 cases per year). There was an increase only for patient hospitalized with PE in other medical facilities (mostly during the second period, 2016-2017, when 20 people were emergently transported to Sofia for thrombectomy). A substantial increase in the absolute number was seen for the CTPA requests by the ER during the second period, but as a portion from all CT requests from the ER, pulmonary angiographies were relatively low in number – approximately 3% a year.

After the implementation of the behavioural protocol, the following tests were performed more often:

- D-dimer tests: for the whole first period of the study (2011-2015), 948 samples were tested, while for the following 2-year period, 851 samples were tested. D-dimer testing was entered in the panel of mandatory laboratory tests in cases

**Table 4.** Generalized presentation of the patient flow and performed interventions for the whole period of the study (2011 – 2017)

| Emergency Room | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** |
|---|---|---|---|---|---|---|---|
| Total examinations | 25703 | 27630 | 32312 | 34456 | 36747 | 37469 | 38845 |
| PE | 42 | 54 | 53 | 55 | 52 | 48 | 54 |
| Hospitalized in UMHAT – Pleven with PE | 39 | 43 | 44 | 44 | 42 | 34 | 37 |
| Hospitalized in another medical facility | 0 | 1 | 2 | 0 | 7 | 9 | 11 |
| Deaths by PE | 3 | 11 | 9 | 11 | 10 | 6 | 7 |
| D-dimer | 19 | 203 | 199 | 242 | 285 | 397 | 454 |
| Total CT requests from the ER | 90 | 1002 | 1045 | 1213 | 1324 | 1346 | 1643 |
| Pulmonary angiographies | 6 | 12 | 16 | 20 | 25 | 34 | 55 |
| Portion of pulmonary angiographies from the total number of CT scans | 7% | 1% | 2% | 2% | 2% | 3% | 3% |

with a low probability of PE, so the increased amount of tests is a logical result;

- CTPA: during the first period, 79 of these were requested by the ER, while for the significantly shorter second period, there were 89 requests;
- The number of performed EchoCG increased as well – from 41% for suspected PE during the first period to 52% in the second period. A decrease is only noticed for the number of patient deaths due to PE (Table 4).

## Discussion

Currently, there is no a 100% credible method for diagnosing PE, because of the variety in its forms, transitory vessel changes, and the risk to accept a false negative result if the test is late. Besides, the interpretation of the panel of tests is difficult, because there is PE with normal test results. Clinical data and a proven factor justify a diagnostic imaging scan/spiral computed tomography with contrast (CTPA), and the latter solves the diagnostic dilemma.

The disadvantages are associated with the ionizing radiation and side effects from the contrast agents [21, 22]. Worldwide, worldwide, medical radiation and mostly X-ray diagnostic imaging are a primary factor in artificial radiation exposure [4, 18, 23]. The concept for justifying the medical radiation exposure of people was later developed in the International Commission on Radiology Protection (ICRP`s) Publication 60 (1990), in the International Basic Safety Standards for Radiation Protection, the Safety of Radiation Sources, and in the European Council directive 84/466/Euratom and 97/43/Euratom [5, 6, 20, 24-26]. Directive 97/43/Euratom states that "Medical exposure shall show a sufficient net benefit, weighing the total potential diagnostic or therapeutic benefits it produces, including the direct health benefits to an individual and the benefits to society, against the individual detriment that the exposure might cause, taking into account the efficacy, benefits and risks of available alternative techniques having the same objective but involving no, or less exposure to ionizing radiation" [4].

The other disadvantage of contrast lung CT is the side effects of the contrast medium itself. The modern contrast agents are usually tolerated very well by the patients, but with the intravascular application, they can still, during the test or later, feel side effects [26].

Modern methods allow performing of the so called "all in one" protocol [20], i.e. successive performing of angiopulmography and phlebography of the lower extremities during one test, without applying additional contrast medium [7].

Our aim was to improve the diagnosing of patients with PE. To complete this challenge, we set specific goals: to find out how many of the patients, admitted in the ER at the University Hospital – Pleven had PE, what their complaints were and, over the years, covered by this study, what imaging tests were performed, whether any errors were found. We aimed to optimize the currently existing protocol for dealing with PE in the ER, and by that improve the usage of CT.

## Conclusions

After the implementation of the protocols, created according to the criteria of Wells and PERC, there was a significant increase in the D-dimer tests, echocardiographies (EchoCGs) and CTPA. Despite the patients' radiation exposure increase, the ER teams disciplined themselves and diagnosing of PE in the ER was significantly improved. The increased amount of patients, transported for thrombectomy was an utterly positive fact, and the absolute decrease of PE mortality in the ER proves the safety of the PERC, combined with the rule of Wells.

Overall, the intervention on the behaviour of the ER teams has a significant positive effect on the management of patients with suspected PE.

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