The 35-mm rule to guide pneumothorax management: Increases appropriate observation and decreases unnecessary chest tubes

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INTRODUCTION: Axial imaging has allowed for more precise measurement and, in-turn, more objective guidelines related to the management of traumatic pneumothoraces (PTXs). In 2017, our trauma center used a guideline to observe any PTX ≤35 mm in stable patients. We hypothesize that this guideline would decrease unnecessary chest tubes without affecting failure rates.

METHODS: This is a single-center retrospective review of all adult trauma patients who had a PTX diagnosed on computed tomography before (2015–2016) and after (2018–2019) guideline implementation. We excluded patients with chest tubes inserted before computed tomography, concurrent hemothoraces, mechanical ventilation, or mortality in the first 24 hours. Descriptive statistical analyses, $\chi 2$ test, and Mann-Whitney U test were performed as appropriate.

RESULTS: A total of 266 patients met our inclusion criteria. Ninety-nine (37.2%) and 167 patients (62.7%) were admitted before and after 2017, respectively. Overall, there were no differences in demographics or severity of injuries between both groups. After guideline implementation, there was a significant increase in observation rates and compliance rate. Tube thoracostomies decreased from 28.3% to 18% ($p = 0.04$). There were no statistically significant changes in observation failure rates, hospital or intensive care unit length of stay, complications, or mortality.

CONCLUSION: The implementation of the 35 mm guideline is an effective tool to decrease unnecessary tube thoracostomy in hemodynamically normal patients without evidence of hemothorax. (*J Trauma Acute Care Surg.* 2022;92: 951–957. Copyright © 2022 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapeutic/care management, level III.

KEY WORDS: Observation; pneumothorax; chest trauma; tube thoracostomy.

Traumatic pneumothoraces (PTXs) account for one of the most common etiologic entities found in trauma patients.[1] Chest x-rays (CXRs) have been commonly used to rapidly detect this potentially life-threatening injury, but with the ubiquitous use of more sensitive imaging studies like computed tomography (CT) scans, health care practitioners have been able to identify smaller PTXs.[2,3]

In the early 1990s, physicians questioned the effectiveness of tube thoracostomies (TTs) in the management of occult PTXs, defined as those PTXs small enough to only be detected on a CT scan.[4] The results showed that this patient population could be safely observed.[5] The promising results of this study became the foundation to expand the patient population that could be safely observed. Further studies analyzed the effects of observation in patients with overt PTXs and even those undergoing positive pressure ventilation, showing favorable outcomes.[6–10]

The understanding of the impact of PTX size in patient's outcomes also led to better patient selection for successful observation.[11,12] After comparing different single measurements to a criterion standard, it was found that the biggest pocket of air obtained from the radial distance between the parietal and visceral pleura in an axial image was the most user friendly measurement while not losing any significant sensitivity or specificity.[13] The cutoff established for a successful observation was determined to be 35 mm in patients with blunt or penetrating trauma.[14]

In 2017, our institution created a guideline to observe all hemodynamically stable patients with PTXs sizes ≤35 mm detected on CT scan. Now, after 2 years of this guideline implementation, it is time to evaluate its efficacy. We hypothesize that adherence to the 35 mm guideline is associated with a decrease use of TT with no additional complications.

PATIENTS AND METHODS

This is a single-center retrospective review of Froedtert Hospital's Level I Trauma Center's trauma registry. This study protocol was approved by the Medical College of Wisconsin Institutional Review Board and is compliant with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/C337).

We included all patients 18 years or older who were admitted to the trauma center after sustaining a thoracic injury based on thoracic Abbreviated Injury Scale scores, in the periods of 2015 to 2016 and 2018 to 2019. Patients admitted in 2017 were excluded because of the new guideline being in the process of implementation and to develop a window for adaptability to it. We excluded patients who were transferred from a referring hospital, died within the first 24 hours, underwent resuscitative thoracotomy in the emergency department, had a TT or needle decompression before CT scan, or required mechanical ventilation. Patients with negative CT findings or presence of concomitant hemothorax were also excluded (Fig. 1).

Data variables including patient demographics, arrival vital signs, body measurements, injury regions found on Abbreviated Injury Scale scores, hospital length of stay, and complications were obtained from the trauma registry. Additional details such as specific injuries identified on CT were pulled from the Electronic Health Record, EPIC (Madison, WI). The PTX dimensions were obtained by two nonradiology research physicians. The mean of two measurements of the largest pocket of air obtained from the radial distance between the parietal and visceral pleura on axial imaging of the CT scan were used to determine the PTX size. Patients with bilateral PTXs were handled as single patients for collection of demographics, injury findings, and hospital stay. However, PTXs were measured separately and treated as two separate entities.

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Observation was defined as any patient who did not receive a TT or require a thoracic procedure within the first 4 hours of admission. Those who required a TT after being initially observed were considered as a failure of observation. Reasons for observation failure were physiologic deterioration (respiratory rate higher than 30 breaths per minute, SpO_2 <90% with FiO_2 21%, or hemodynamic changes attributed to the pneumothorax), intraoperative tube insertion following thoracic surgery, presence of new hemothorax, and significant increase in PTX size. Traumatic pneumothorax enlargement was assessed on a routinely ordered CXR 4 to 6 hours after the CT scan and then a repeated CXR the following day. In those cases where there was a concern for an enlarging hemothorax on CXR, we repeated a CT scan to quantify the hemothorax and discern between contusion and hemothorax. If the reason for TT was not specified, it was defined as unclear reason.

The primary outcomes were the observation rates before and after the guideline. Secondary outcomes were observation failure rates, length of hospital stay, intensive care unit length of stay, pulmonary-related complications, and 30-day readmission.

Data were analyzed using IBM SPSS Statistics for Windows. χ^2 and Mann-Whitney *U* tests were used to evaluate the differences between the two different groups.

TABLE 1. Descriptive Characteristics of Patients With Pneumothorax Before and After the 35 mm Guideline Implementation

	Before Guideline Implementation	After Guideline Implementation	Total	
Variable	**n = 99**	**n = 167**	**n = 266**	***p***
Age, median (SD), y	37 (20.2)	37 (18.4)	37 (19)	0.87
Male, n (%)	64 (64.6)	107 (64)	171 (64.3)	0.92
Race, n (%)				0.73
White	58 (58.5)	101 (60.4)	159 (59.8)	
Black	36 (36.3)	61 (36.5)	97 (36.5)	
Other	5 (5)	5 (3)	10 (3.8)	
Mechanism of injury, n (%)				0.77
Blunt	95 (96)	159 (95.2)	254 (95.5)	
BMI, median (SD), kg/m^2	25.9 (5.3)	25.5 (6.5)	25.5 (6)	0.58
ED respiratory rate, median (SD)	18 (4.4)	20 (4.4)	20 (4.4)	0.23
ED systolic blood pressure, median (SD), mm Hg	135 (25.9)	132 (23.3)	132 (24.3)	0.56
ED diastolic blood pressure, median (SD), mm Hg	80 (14.1)	78 (15.1)	79 (14.7)	0.31
ED heart rate, median (SD), bpm	86 (15.9)	90 (18.3)	89 (17.4)	0.53
Glasgow Coma Scale, n (%)				0.41
13–15	95 (95.9)	161 (96.4)	256 (96.2)	
9–12	4 (4)	4 (2.3)	8 (3)	
<9	0 (0)	2 (1.1)	2 (0.8)	
Injury Severity Score, median (SD)	14 (8)	13 (8.1)	14 (8.1)	0.14
Pneumothorax size, median (SD)	9 (12.1)	10 (13.9)	9 (13.3)	0.28
No. rib fractures on pneumothorax site, n (%)				0.75
0	34 (34.4)	50 (29.9)	84 (31.6)	
1–3	31 (31.3)	57 (34.1)	88 (33.1)	
>3	34 (34.4)	60 (35.9)	94 (35.3)	
No. rib fractures on opposite site, n (%)				0.95
0	81 (81.8)	134 (80.2)	215 (80.8)	
1–3	13 (13.1)	24 (14.3)	37 (13.9)	
>3	5 (5)	9 (5.3)	14 (5.3)	
Flail chest, n (%)	3 (3)	2 (1.1)	5 (1.9)	0.36
Bilateral pneumothorax, n (%)	17 (17.2)	38 (22.8)	55 (20.7)	0.27
Pulmonary contusion, n (%)	51 (51.5)	105 (62.8)	156 (58.6)	0.06
Diaphragmatic injury, n (%)	0 (0)	2 (1.1)	2 (0.8)	0.53
Abdominal injury, n (%)	22 (22.2)	45 (26.9)	67 (25.2)	0.39
ED disposition, n (%)				0.36
Floor	55 (55.5)	87 (52)	142 (54)	
Operating room	9 (9)	14 (8.3)	23 (8)	
ICU	35 (35)	61 (36.5)	96 (36.7)	
OR intervention for chest injury, n (%)	3 (3)	4 (2.3)	7 (2.6)	0.71
Smoker, n (%)	30 (30)	43 (25.7)	73 (27.4)	0.42
COPD, n (%)	2 (2)	2 (1.1)	4 (1.5)	0.59

BMI, body mass index; bpm, beats per minute; COPD, chronic obstructive pulmonary disease; ED, emergency department; OR, operating room; ICU, intensive care unit.

RESULTS

A total of 1,485 patients with traumatic chest injuries were admitted in the periods 2015 to 2016 and 2018 to 2019. Of those, 1,219 patients were excluded as they did not meet our criteria, resulting in a total of 266 patients in our final study population (Fig. 1).

Sixty-two percent of our patients were admitted after the 35 mm guideline implementation. There were no significant differences in the demographics or injury characteristics between both groups (Table 1). Admitted patients in these groups had sustained predominantly blunt trauma (95.5%). On arrival to the trauma center, CT scan showed an average PTX size of 9 mm (SD, 12.1 mm) and 10 mm (SD, 13.9 mm) before and after guideline, respectively. In addition, one in every four patients with a PTX presented with a concomitant abdominal injury.

After guideline implementation, chest tube utilization decreased, which was reflected in higher observation rates from 84.8% to 94.6% ($p = 0.007$). When measuring compliance with the 35 mm guideline in different hours, we found that both groups were similar at 4 hours, but after 24 hours, compliance rates decreased in the group before the guideline implementation ($p = 0.04$) (Table 2).

There were no differences found in observation failure rates or length of hospital stay. The most common reason for observation failure was presence of a new hemothorax (41% of patients), followed by unspecified reasons for TT insertion. Pulmonary-related complications remained similar between both groups, with postpull PTX being the most common complication in patients treated with a TT.

Of all patients, six were readmitted within 30 days of discharge, and only two presented with a pulmonary-related issue (one patient was readmitted with an empyema 6 days after discharge, and one patient who was successfully observed presented with dyspnea secondary to a PTX 3 days after discharge).

DISCUSSION

The implementation of a guideline to observe hemodynamically stable patients with PTXs ≤35 mm increased observation rates after 2 years of its implementation while maintaining compliance with the guideline, without an increase in observation failure, length of stay, or complication rates.

With the widespread use of chest CT imaging and the increasing diagnosis of small PTXs in the past decades, many health care practitioners have opted to observe these PTXs, but the controversies and differing opinions in the literature in regard to the most appropriate management have shown that current observation rates vary from 70 to 80%.[10,15–17] In general, our trauma center culture was to observe small PTXs even before the guideline implementation, with an observation rate of 85%. However, how a clinician defined small was not based on any guideline. The addition

TABLE 2. Outcomes of Patients With Pneumothorax Diagnosis, Before and After 35-mm Guideline Implementation

	Before Guideline Implementation	After Guideline Implementation	Total	
Variable	**n = 99**	**n = 167**	**n = 266**	***p***
No. patients receiving chest tubes, n (%)	28 (28.3)	30 (18)	58 (21.8)	0.04
Compliance with 35 mm guideline (4 h), n (%)	90 (90.9)	153 (91.6)	243 (91.4)	0.84
Compliance with 35 mm guideline (24 h), n (%)	81 (81.8)	151 (90.4)	232 (87.2)	0.04
Length of stay, median (SD)	4 (3)	4 (25.1)	4 (20)	0.82
ICU days, median (SD)	0 (1.6)	0 (1.7)	0 (1.7)	0.62
Complications, n (%)	4 (4)	10 (5.9)	14 (5.2)	0.49
Observation, n (%)	84 (84.8)	158 (94.6)	242 (91)	0.007
Observation failure, n (%)	13 (13.1)	21 (12.6)	34 (12.8)	0.62
Reason for failure, n (%)				0.90
New hemothorax	5 (38.4)	9 (42.8)	14 (41.1)	
Physiologic deterioration	0 (0)	0 (0)	0 (0)	
Pneumothorax progression	3 (23)	3 (14.2)	6 (17.6)	
Postsurgery	0 (0)	1 (4.7)	1 (2.9)	
Unclear	5 (38.4)	8 (38)	13 (38.2)	
Thoracic procedure, n (%)				0.63
VATS	1 (1)	2 (0.1)	3 (1.1)	
Rib fixation	1 (1)	2 (0.1)	3 (1.1)	
Pulmonary-related complications, n (%)	5 (5.1)	5 (3)	10 (3.8)	0.39
Pneumonia	0 (0)	2 (1.1)	2 (0.8)	0.53
Empyema	0 (0)	0 (0)	0 (0)	—
Lung abscess	0 (0)	0 (0)	0 (0)	—
Pulmonary embolism	1 (1)	1 (0.6)	2 (0.8)	1
Postpull pneumothorax	4 (14.8)	3 (10)	7 (12.1)	0.61
Readmission, n (%)	1 (1)	5 (3)	6 (2.3)	0.41
Mortality, n (%)	1 (1)	0 (0)	1 (0.3)	0.37

Observation failure: Patient who after 4 hours of observation underwent a TT.
ICU, intensive care unit; VATS, video-assisted thoracoscopic surgery.

of the 35 mm guideline increased observation rates up to 94.6%. We suspect that this impact will be much higher in those centers that have greater variability in the decision tree to place a TT.

When measuring guideline compliance, we found that compliance rates were very similar in the first 4 hours of admission, but it decreased significantly at 24 hours in the group before the guideline. This finding suggests that the familiarity with the implementation of a guideline may have impacted the management and comfort that physicians had at the moment of managing patients whose PTX was borderline in terms of size.[18]

Observation failure rates remained similar between both groups at 12% after the 35 mm guideline was implemented, with presence of a new hemothorax as the most common reason for observation failure (41.1%) followed by PTX progression (17.6%), found on a routine imaging study (CXR or CT scan) at 4 or 24 hours, or if the surgeon thought necessary. In our study, none of the patients who failed observation presented with physiologic deterioration secondary to a PTX.

In the current literature, 22% of patients undergoing TT have an associated morbidity with the procedure.[8,19] In our study,

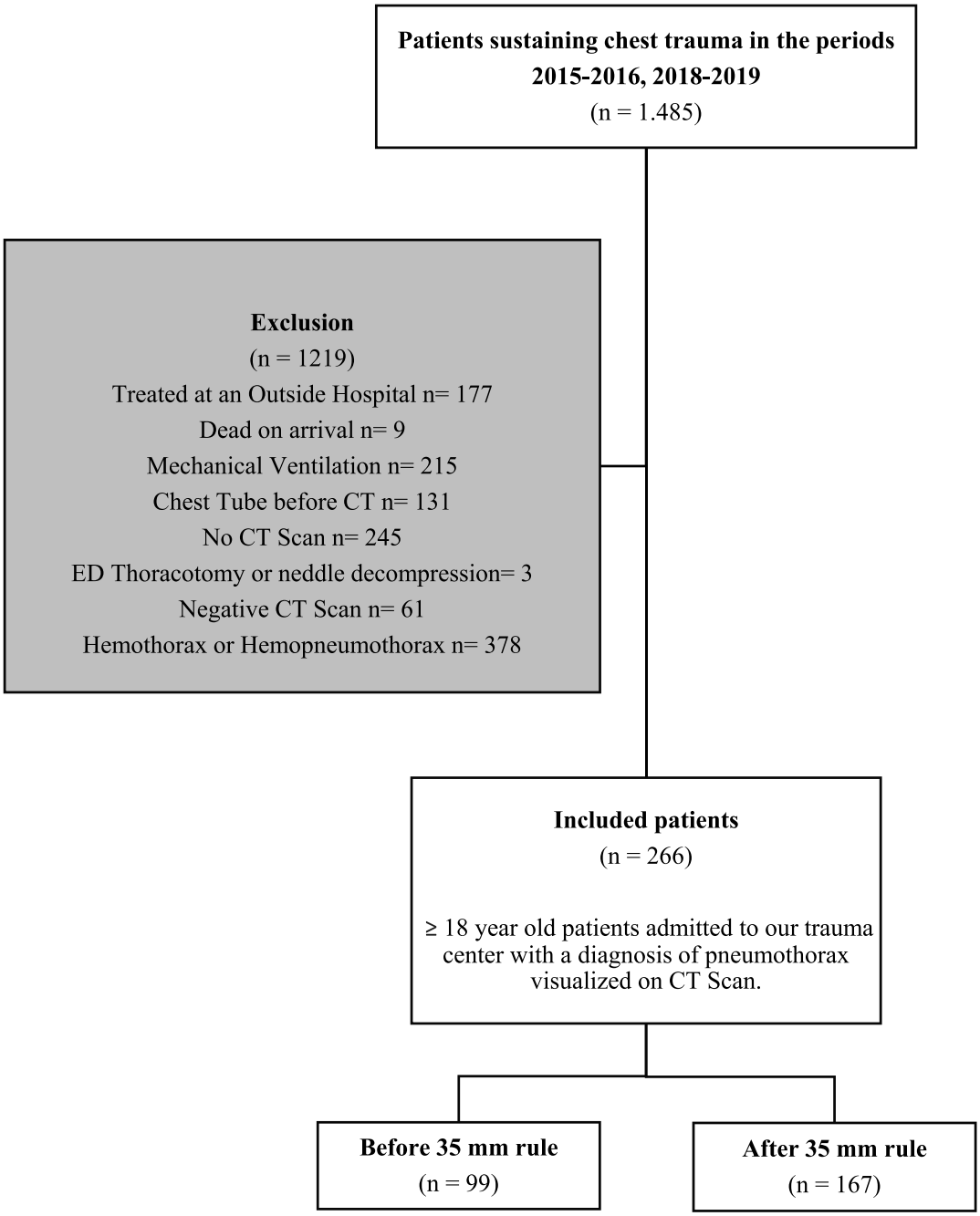

Figure 1. CONSORT flow diagram. ED, emergency department.

the most frequent pulmonary-related complication was evidence of a postpull PTX in both groups.

The retrospective nature of this study posed a number of typical issues. It prevented us from determining the clinical decision for TT of 38% patients who failed observation. In addition, it did not allow us to measure additional morbidities associated with TT insertion, such as postprocedural pain, bleeding, and impact on function that could have been overlooked in the patient's medical record. The sample size of this study is relatively small, and the low rate of complications precluded us from analyzing the effect of the guideline on these complications. We excluded patients with hemopneumothorax and those under positive pressure ventilation because our guideline was limited to PTXs, but we believe that these patient populations may benefit from guidelines for observation as well.[6] These factors emphasize the need for a more comprehensive and collaborative prospective study to further help us understand the decision-making process for placing a TT, analyze additional complications of TT insertion, and study the impact that this guideline has in hospital costs, and human and infrastructural resources in a larger study population.

CONCLUSION

In conclusion, the implementation of the 35 mm guideline is an effective tool to decrease unnecessary TT placement by increasing the patient population observed while maintaining patient safety in hemodynamically normal patients without evidence of hemothorax.

AUTHORSHIP

J.F.F., B.S.K., J.G., and M.A.d.M. contributed in the concept, acquisition, analysis, and interpretation of data. J.F.F., B.S.K., J.G., M.A.d.M., D.M., R.S.M., C.D., T.C., P.M., A.E., and M.S. contributed in the drafting, literature search, and critical revision of the manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

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DISCUSSION

STANISLAW P. STAWICKI, M.D. (Bethlehem, Pennsylvania): Good Afternoon. Nice to be at a meeting that's in person in quite a long time. Thanks to AAST leadership, Program Committee, our session moderators and Dr. Figueroa, et al.

I will first comment that it's nice to see some good research here and especially some very relevant clinical research. The scientific program is very much appreciated for that, and there are many valuable teaching points during the sessions.

At this time, I'm going to group my questions to you into three categories. And the first one is going to be protocol-related, about your actual protocol. The second group of questions is going to be about the failure mode. You mentioned that pneumothorax is now the most common failure mode. I will comment on that in a second. And finally, chest tube-related questions.

So in terms of protocol, I assume that you actually have a protocol with maybe some sort of pocket card, a "cheat sheet," or something along those lines that everybody carries and it's discussed in the morning report, correct?

Is this part of a larger protocol that considers chest tube maintenance or other chest tube related issues? Or is it a stand-alone protocol?

Now, if it is a chest tube protocol, does it also include other variables that may relate to chest tube insertion such as prophylactic antibiotics or other points related to safety and/or quality of care?

Also within that context, I would like to add that it is important to know that the "3.5 radiographic rule" is just one way to look at pneumothoraces, and there are certainly other rules.

These other rules been published in the past where you look at hemithorax, the percent circumference, subcutaneous

air, other findings that maybe associated with failure of non-procedural therapy. So within that first procedural, protocol-related set of questions I would like for you to address that.

In terms of the actual failure mode, I would like to see your data, if it's possible to abstract relevant variables, on anticoagulant use, because it has been increasing over the years. I am curious whether or not that contributes to the hemo-pneumothorax part and whether or not penetrating mechanisms may have something to do with that.

And then, finally, in terms of chest tube complications and chest tube related considerations, again, I think it would be great to know "blunt versus penetrating" trauma, are there any differences between those two groups?

In addition, and somewhat unrelated to the current presentation but very important nonetheless, one thing that I think there is a huge need to do more research on, is the BMI of the patients versus complication rates. I think if you check Google Scholar, and this is just kind of a general comment, the actual terms "chest tube" "morbid obesity" there are just about "zero references" that one can find and I think that that's an area that your dataset may be able to answer.

And that's all I have. Wonderful job. Thank you for a very fine presentation. And thanks again to AAST Program Committee – I appreciate the opportunity to be a discussant for this important paper.

ROSEMARY A. KOZAR, M.D., Ph.D. (Baltimore, Maryland): Nice presentation. I just have a couple of quick questions about your methods.

First, at 3.5 I'm assuming you cannot see the pneumothorax on a plain chest x-ray? And so when you gave us the information on the 4-hour and the 24-hour findings, these are based on plain chest X-ray? You are not rescanning these patients, correct?

JUAN F. FIGUEROA, M.D. (Wauwatosa, Wisconsin): So, yes, I'm going to start with your question. So what we usually do is first we assess these patients in different ways.

And for the matter of building this study we just collected the data of the patients that additionally to the chest x-ray they got a CT scan. That's not something we always do. But for matters of the study we just collected that data group.

And then after that if these patients developed any problem throughout the day then they will be re-scanned with a chest x-ray, most likely. And if the process is needed they might have to go to a CT scan.

But compliance 24 hours was just based on the initial CT scan. We didn't re-measure it. In I would say most patients we didn't re-measure it unless they developed something that guaranteed to find the underlying problem.

ROSEMARY A. KOZAR, M.D., Ph.D. (Baltimore, Maryland): You might want to go back and look at how many patients actually had a pneumothorax, and clarify what led to the chest tube placement. You would have to know what your findings are, I'm assuming, as you did a follow-up chest x-ray at 4 hours and 24 hours.

JUAN F. FIGUEROA, M.D. (Wauwatosa, Wisconsin): Yes, correct. So if the patient developed – that's something, one of the limitations that we, it's hard to understand what was the reasoning behind the management, what signs and symptoms the patient presented to get a new chest x-ray or a new CT scan.

The most common reason for failure was a new pneumothorax. Patients probably started referring pain and a little bit of shortness of breath, chest x-ray went by. There was some angle that covered (Indistinguishable), a blunting side.

And possibly if there was nothing on chest x-ray they progressed it to a CT scan, again, to confirm the diagnosis. And that's the only reason why they could get a new image.

Otherwise, they will get a chest x-ray 24 hours just as a standard. If the patient is doing well and then – I'm sorry. It's hard to respond sometimes to questions in front of people.

So with regards to the protocol, the chest tube protocol was built and implemented between our team as a guideline, as a foundation to be used by our doctors.

This is something that has been, of course, taught throughout the time in between cases, presenting cases in the mornings when it is necessary. But then this is not a rule. This is not completely mandated. It's a guideline just to guide decisions.

And, as you can see, that possibly impacted the way that the compliance improvement was there because with this foundation, with the data in place now we were able to confidently observe these patients.

With regards to antibiotics, new studies have come up and meta analyses of CTs out there and now we're trying to work on improving our protocol to use antibiotics in patients that are receiving a chest tube nowadays. But in the moment when we collected our data we didn't use antibiotics.

And taking into account other possible measurements that could affect the patient's outcome and failure in observation, like the 50 percent pneumothorax measurement, or subcutaneous emphysema was, in our study we didn't take into account but the 35 millimeter rule has covered most of these cases and these patients. And we know that just being confident in the use of the 35 millimeter rule we could cover all these underlying risk factors.

With terms of pneumothorax, in our study we didn't include it as part of our guideline but as part of the clinical ground we have a separate guideline to measure this pneumothorax where we observe any pneumothorax that is below 300 ccs. If they were both together in the clinical setting we probably would observe these patients at the same time.

And with regards to anticoagulation, we didn't see the data in these patients that develop a new pneumothorax if they had anticoagulation. But this is an important aspect because if we're going to observe these patients we've got to be careful that these patients will develop a big pneumothorax that will require a chest tube. Probably that could be a risk factor and that patient could potentially benefit for a chest tube insertion.

And with regards to obesity and the penetrating and blunt trauma injuries, those factors were not associated, were not searched in our study as observation failure factors because our study was mainly focused to evaluate the effect of this guideline.

But the previous study, the study before this one assessed the observation failure factors and BMI was not one. And the patients with penetrating and blunt trauma do exactly, they have similar outcomes when we observed them because if you take into account the physiologic component of a blunt trauma, it can be a little mixed.

Initially it's blunt in nature but then there are ribs that get fractured and displaced and then they end up lacerating just like a stabbing knife. So both patients in the previous study, both groups did well.