Long-term Outcome in Chest Trauma

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Background: Currently, there are limited data available describing the long-term outcomes of chest trauma survivors. Here, the authors sought to describe chest trauma survivor outcomes 6 months and 1 yr after discharge from the intensive care unit, paying special attention to pulmonary outcomes.

Methods: A cohort of 105 multiple trauma patients with blunt chest trauma admitted to the intensive care unit was longitudinally evaluated. After 6 months, a chest computed tomography scan, pulmonary function testing (PFT), and quality of life were collected in 55 of these patients. A subgroup of 38 patients was followed up for 1 yr.

Results: At least one abnormal PFT result was found in 39 patients (71%). Compared with normalized data of the age- and sex-matched population, physical function was decreased in 38 patients (70%). The 6-min walk distance was reduced for 29 patients (72%). Although pathologic images were observed on the chest computed tomography scan from 33 patients (60%), no relation was found between PFT and computed tomography. A ratio of arterial oxygen pressure to inspired oxygen fraction less than 200 at admission to the intensive care unit predicted an abnormal PFT result at 6 months. One year after discharge from the intensive care unit, paired comparisons showed a significant increase in forced vital capacity ($P = 0.02$) and Karnofsky Performance Status ($P < 0.001$).

Conclusions: Survivors of multiple traumas including chest trauma demonstrate a persistent decrease in the 6-min walk distance, impairment on PFT, and reduced pulmonary-specific quality of life.

◆ This article is accompanied by an Editorial View. Please see: Dutton RP: Measuring the true cost of trauma. ANESTHESIOLOGY 2008; 109:773–4.

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A LARGE body of literature has demonstrated altered pulmonary function testing results and quality of life in patients who survive acute respiratory distress syndrome (ARDS).[1–5] Patients who survive blunt chest trauma are at risk of physical disturbances. However, to the best of our knowledge, there is a lack of data for predicting the long-term outcome of these patients. The goal of this study was to characterize long-term pulmonary sequelae in a cohort of survivors having multiple trauma with blunt chest trauma (MTBCT). Our hypothesis was that, 6 months after their discharge from the intensive care unit (ICU), the rate of impaired spirometry was higher in these patients than in the general population. Relations between patients' characteristics and outcomes were also determined.

Materials and Methods

This prospective longitudinal follow-up study of survivors of MTBCT was conducted in a closed-format, 16-bed, medicosurgical ICU in the University North Hospital of Marseille (Marseille, France) from November 2003 to May 2006. In this ICU, all patients alive at discharge from the ICU are systematically included in a medical follow-up program performed by one of the physicians. The study was conducted in accordance with French legislation and was approved by the ethics committee of the French Language Society of Critical Care Medicine (Paris, France). Initial informed consent was also obtained from the patient or relatives. In addition, written informed consent was obtained from each patient at the time of each visit.

Study Population and Selection of the Study Cohort

During the 32-month inclusion period, we prospectively screened trauma patients older than 18 yr with an Injury Severity Score of 15 or higher[6] and an abnormal chest computed tomography (CT) scan performed at ICU admission. For this study, we excluded pregnant women; patients with a previous history of chronic respiratory or cardiac failure, documented psychiatric disease, previous history of chest trauma, concomitant spine trauma responsible for neurologic deficit, or Glasgow Outcome Score[7] of 2 or less at discharge from the ICU; and patients who lived more than 150 km from our hospital.

Of the 522 trauma patients who were admitted to the ICU for MTBCT during the study period, 105 adults had chest trauma, defined as follows: thoracic abbreviated injury scale of 2 or greater[8] and at least one pulmonary
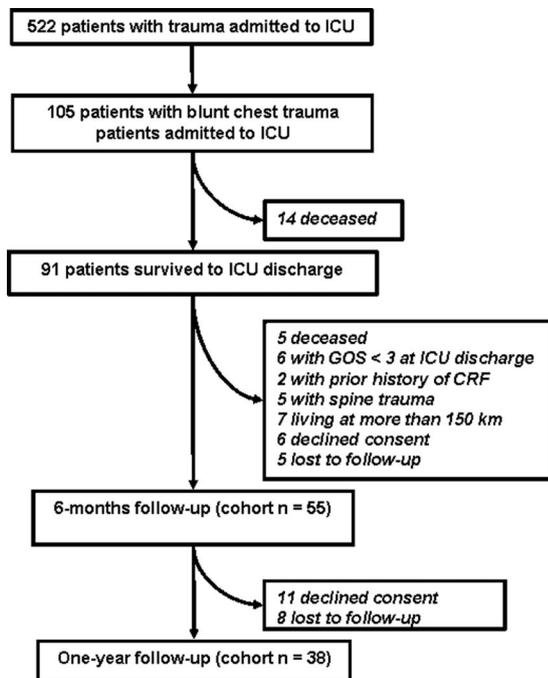
Fig. 1. Flow chart of inclusions. CRF = chronic respiratory failure; GOS = Glasgow outcome score; ICU = intensive care unit.

contusion on chest CT scan. Ninety-one patients (87%) were alive at discharge from the ICU (fig. 1). Five patients died before the 6-month assessment as a result of head trauma (n = 3), pulmonary embolism (n = 1), or septic shock (n = 1). Five patients were lost during follow-up, and 6 did not consent to follow-up. Twenty patients were excluded for reasons detailed in figure 1. The remaining 55 patients were included and were visited at least once, at 6 months; 38 of these patients were seen again after 1 yr. The patients' characteristics and treatments were prospectively registered in a central database.

Follow-up Program

At discharge from the ICU, the patients were informed that they would be contacted by phone and letter to plan a consultation with one trained physician in the next 6 and 12 months. This consultation was associated with a chest CT scan and pulmonary function testing (PFT). It was also specified that the patients would be asked to respond to self-administered questionnaires on their quality of life and to an interview based on a structured questionnaire. Details on the content of each visit, chest CT scan, and PFT assessment were given in the letter mailed the month before the first expected visit.

Assessment

Six months after discharge from the ICU, the survivors were scored for their health status and activities. Next,

patients were evaluated in the lung function laboratory for PFT, blood gas analysis, physical performance measurement using the 6-min walk distance, and pulmonary-specific health-related quality of life using St. George's Respiratory Questionnaire.[9] Patients underwent chest CT scanning, and a second assessment without CT scanning was performed in 38 patients after 1 yr. The follow-up was performed by a trained interviewer (F.B.).

Six-minute Walk Distance. The 6-min walk distance was measured according to the standard recommendations[10] and was compared with normative population values.[11] Episodes of desaturation (5% decrease in arterial oxygen saturation [SaO_2] compared with baseline values) were recorded. Dyspnea upon exercise was assessed with a 10-cm visual analog scale (ranging from 0 = none to 10 = asphyxia).

Pulmonary Function Testing. Forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), forced expiratory volume measured between 25% and 75% of vital capacity, airway resistance, functional residual capacity, and total lung capacity (TLC) were measured with a whole body pressure displacement plethysmograph (MasterLab Jaeger, Bunnik, The Netherlands). The carbon monoxide diffusion capacity adjusted for hemoglobin and the carbon monoxide diffusion capacity adjusted for alveolar volume were measured using the single-breath technique with an infrared analyzer. A breath-holding time of approximately 10 s was determined by the Jones–Meade method.[12] Analyses of spirometry conformed to the standards of the American Thoracic Society.[13,14] At rest, arterial blood gas was analyzed from the ear lobe capillary arterialized blood while the subject breathed room air and was in the sitting position (Corning-Chiron model 860; Bayer Corporation, East Walpole, MA).

Questionnaires. Based on a structured questionnaire administered by the interviewer, the actual and preinjury status for the following were recorded: smoking habits, lung diseases, dyspnea, and daily activity. Dyspnea was assessed by the New York Heart Association Classification. The ability to perform ordinary tasks was assessed using the Karnofsky Performance Status.[15] The current study was focused on lung/dyspnea-specific instruments, including St. George's Respiratory Questionnaire, as described previously.[2,9,16] To ensure the good understanding and adequacy of the responses, the questionnaire was completed during a face-to-face interview (F.B.), as recommended in the St. George's Questionnaire's administration description section of the American Thoracic Society Quality of Life Resources Instruments.†† The questionnaire was applied in a quiet environment. The patient answered the questions without interference. For illiterate patients, the interviewer read the questions and answered alternatives aloud, verbatim (without explanations). For the purpose of the two periods of follow-up, the questionnaire was modified as-

†† Available at: http://www.atsqol.org. Accessed July 08, 2008.

sessing items from the past 6 months instead of the past 12 months. In addition, because patients were supposed to have comorbidities that could interact with the lung origin of the symptoms, the phrase "because of your lungs" was added at the end of each sentence.

Other Measurements

CT Scans. All patients underwent a chest CT scan after ICU admission and at 6 months. The CT scans were performed with a 64-row multidetector CT (Somatom Sensation 64; Siemens, Erlangen, Germany). Each chest CT scan was interpreted by the same senior physician (K.C.) using a research worksheet. Additional information regarding this is available on the ANESTHESIOLOGY Web site at http://www.anesthesiology.org.

Severity of Illness. Characteristics and measurements of severity of illness and trauma in the ICU were collected within the first 24 h after each patient admission to the ICU, using the Simplified Acute Physiology Score,[17] Injury Severity Score,[6] and Glasgow Coma Scale score.[18]

Data Collection. The number of patients requiring tracheal intubation and mechanical ventilation, chest tube placement, and blood transfusion; comorbidities; and the duration of stay were also collected. The ratio of arterial oxygen pressure (Pa_{O_2}) to inspired oxygen fraction (F_{IO_2}) was noted. All the events occurring during the ICU stay were prospectively collected with special attention to hospital-acquired pneumonia,[19] ARDS,[20] hemorrhagic shock,[21] sepsis, and multiple organ failure.[22] At discharge from the ICU, the need for oxygen supplementation and the neurologic status using the Glasgow Outcome Score (1–5) were collected.

Statistical Analysis

Statistical calculations were performed using the software package SPSS 15.0 (SPSS Inc., Chicago, IL). For continuous and ordinal variables, data were expressed as median with interquartile range (25–75% quartiles). For dichotomous variables, percentages were calculated. Comparisons between two subgroups, *e.g.*, the presence or absence of bilateral pulmonary contusion, were performed with the Mann–Whitney U test. Comparisons of percentages, *e.g.*, rates of patients with *versus* without an abnormal test, were performed with the Fisher exact test. Comparisons between two follow-up periods were performed with the paired Wilcoxon test.

Because an abnormal PFT result at 6 months was the major follow-up endpoint, we searched for its predictors using a multidimensional analysis by logistic regression using the forward Wald stepwise model. All of the variables related to the preadmission status and the ICU stay were tested by univariate analysis. The Pa_{O_2}/F_{IO_2} ratio was coded dichotomously as less than 200 and 200 or greater. Only variables with $P < 0.2$ were included in the model. In addition, using the same methodology, we

searched for ARDS risk factors among variables recorded at admission, including the results of the initial chest CT scan.[23] Odds ratios were expressed with 95% confidence intervals. The quality of the model was assessed with the R^2 coefficient and the receiver operating characteristic analysis. Sensitivity, specificity, predictive positive and negative values, and percentage of patients appropriately classified by the model were also computed.

The rate of abnormal spirometry in the general population is approximately 10%,[24,25] whereas a previous study showed that 25% of survivors of trauma had an impaired spirometry.[26] Hence, with respect to this difference, 49 subjects were required to obtain a power of 90% with an α error level at 5%. To ensure enough of a safety margin, we included 55 patients. All comparisons were two tailed. $P < 0.05$ was required to exclude the null hypothesis.

Results

Characteristics of Patients

The characteristics of the 55 included patients with MTBCT are shown in table 1. The dropout population

Table 1. Characteristics of the 55 Patients Included in the Follow-up

Patient Characteristic	Value, n = 55
Age, yr	35 [22–45]
Male sex	43 (78)
Ever smoker	21 (38)
Mechanism of injury	
Motor vehicle accident	44 (80)
Fall	9 (16)
Assault	2 (4)
Associated injuries	55 (100)
Head	32 (58)
Abdomen	23 (41)
Spine	22 (40)
Pelvis	15 (27)
Limbs	28 (51)
Glasgow Coma Scale score at admission	15 [8–15]
Injury Severity Score at admission	22 [18–29]
Simplified Acute Physiology Score II at admission	30 [23–43]
Mechanical ventilation at admission	31 (56)
Chest tube insertion at admission	29 (53)
Duration of stay in intensive care unit	9 [4–17]
Days of ventilator use	3.5 [1–9]
Days of sedative agents	2 [1–6]
Pneumonia in intensive care unit, no. (%)	14 (25)
Acute respiratory distress syndrome	8 (14)
Hemorrhagic shock	6 (11)
Transfusion	13 (23)
Glasgow outcome score = 3 at intensive care unit discharge	10 (18)
Glasgow outcome score = 4 at intensive care unit discharge	3 (6)
Glasgow outcome score = 5 at intensive care unit discharge	42 (76)

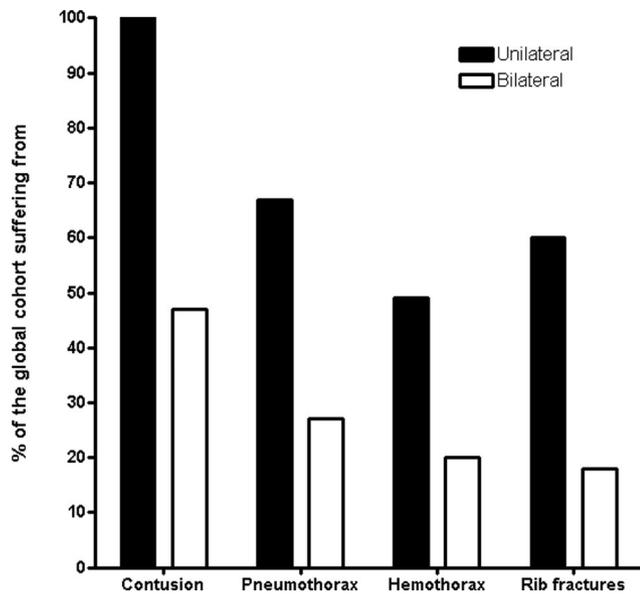Data are expressed as median [interquartile range] and number of patients (percentage).

Fig. 2. Computed tomography scan findings at admission to the intensive care unit of the global cohort (55 patients). *Black bars* indicate the percentages of the global cohort with bilateral contusion, pneumothorax, hemothorax, and rib fractures. *White bars* indicate the percentages of the global cohort with unilateral contusion, pneumothorax, hemothorax, and rib fractures.

did not differ significantly from the remaining cohort at 6 months (data not shown). The tracheas of 31 patients (56%) were intubated in the field. During the early phase of resuscitation, episodes of desaturation ($Sao_2 < 90\%$) and collapse (systolic arterial pressure < 90 mmHg for more than 5 min) were experienced by 12 patients (22%) and 6 patients (11%), respectively. During the first 24 h, 27 (49%) and 13 patients (24%) required volumes of fluid greater than 3 l/day and transfusion of blood products, respectively. Long-bone fractures with potential fat embolus were observed in 23 patients (42%).

Details of the diagnosed chest injuries on the initial chest CT scan are shown in figure 2. Of note, during the ICU stay, 5 patients (9%) with a Glasgow Coma Scale score greater than 10 required a prolonged ICU stay because of respiratory dysfunction. A tracheotomy was performed in 2 patients (4%). An episode of ARDS was diagnosed in 8 patients (14%) (table 1).

Health Status at the 6-Month Follow-up

The individual approach provided at least one abnormal PFT result in 39 patients (71%). Among FVC, $FEV_1/$FVC, TLC, residual volume/TLC, and carbon monoxide diffusion capacity adjusted for hemoglobin, 14 patients (25%) had only one abnormal value, 12 (22%) had two abnormal values, and 10 (18%) had three or more abnormal values. For each test, the median values and interquartiles of the patients with abnormal PFT results are reported in table 2, these values showing moderate to severe ventilatory defects. A mild to moderate obstructive pattern ($FEV_1 < 80\%$ and FEV_1/FVC at 70–80% of predicted value or raw > 2.5 cm H_2O/ml) was observed

Table 2. Results of Pulmonary Function Testing in the Patients with Abnormal Pulmonary Function

Respiratory Variable	Number of Patients with Abnormal Tests	% of Predicted Values
Arterial pressure in oxygen	14 (25)	77 [76–79]
Forced vital capacity	16 (29)	63 [56–70]
Forced expiratory volume in 1 s	19 (34)	74 [61–76]
Forced expiratory volume in 1 s/ vital capacity	9 (16)	65 [63–68]
Forced expiratory flow 25–75%	36 (65)	61 [46–72]
Total lung capacity	6 (11)	73 [68–75]
Residual volume/total lung capacity	25 (45)	135 [130–143]
Carbon monoxide diffusion capacity	31 (56)	63 [59–71]
Carbon monoxide diffusion capacity/alveolar volume	12 (22)	75 [73–77]

Results are expressed as percentage [interquartile range] of the predicted value. Predicted values were calculated using age- and sex-matched population normative data according to the reference values.[13] Data are expressed as median [interquartile range] and number of patients (percentage).

in 24 patients (44%) and was reversible in 13 patients (53%). Four patients (7%) had a restrictive pattern (TLC and FVC below 80% of the predicted value). Two patients (4%) had arterial desaturation after exercise.

With respect to chest CT scans, pathologic images were observed in 33 (60%) of 55 patients, including rib consolidations in 31 patients (56%). Areas of ground-glass opacification were noted in 25 patients (45%). These images were bilateral in 6 cases (11%), on the right lung in 7 cases (13%), and on the left lung in 12 cases (22%). These areas were limited, less than one pulmonary segment in most cases. Reticular pattern was observed in 4 patients (7%). Pleural thickening was seen in only 2 patients (4%).

Based on the structured questionnaire, dyspnea was reported by 36 patients (65%). Compared with preinjury status, more patients were classified in New York Heart Association Classification group II or greater (12% *vs.* 72%; $P = 0.0001$; table 3). Forty-eight patients (90%)

Table 3. General Health Assessment and Lung-related Health Quality of Life at 6 Months

Variable	6 Months, n = 55
Weight, kg	68 [60–76]
Karnofsky Performance Status	80 [70–90]
New York Heart Association Classification	
I	15 (28)
II	29 (52)
III	11 (20)
St. George Respiratory Questionnaire	
Total	9 [3–24]
Symptoms	10 [0–18]
Activity	13 [0–47]
Impact	4 [0–11]

Data are expressed as median [interquartile range] and number of patients (percentage).

satisfactorily fulfilled the self-administered St. George's Respiratory Questionnaire. Table 3 shows the mean score obtained for each of the three domains of the score. The reduced parts of quality of life were activities and symptoms, as attested by the high score values obtained in these domains. The 6-min walk distance was performed in 40 patients (78%). It was reduced (median, 478 m; from 45 to 635 m), resulting in 58% [52–63%] of the predicted distance for 29 patients (72%),[11] primarily for extrapulmonary reasons.

At 6 months, the patients' body weight returned to its initial value as retrospectively recorded (69 ± 13 kg) (table 3). Forty-two patients (86%) returned home, whereas 7 (14%) lived in a rehabilitation center. Whereas none of the patients had a Karnofsky Performance Status below 90 in the preinjury status, 38 patients (70%) scored below 80 at 6 months ($P < 0.001$; table 3).

Bilateral versus *Unilateral Pulmonary Contusion*

To elucidate the potential role of the pulmonary contusion, we compared the 26 patients who had bilateral contusion with the 29 patients who had unilateral contusion. The patients with bilateral contusion were younger than those with unilateral contusion (22 [19–40] *vs.* 40 [25–49] yr; $P = 0.03$), but their Injury Severity Scores were similar (24 [15–32] *vs.* 20 [18–29]; $P = 0.7$). Interestingly, using a univariate analysis, four variables that were recorded at admission were associated with the occurrence of ARDS: multiple blood product transfusion, bilateral contusion, bilateral hemothorax, and a Pao_2/Fio_2 ratio less than 200. The multivariate analysis showed that bilateral pulmonary contusion (odds ratio = 6 [2–25]; $P = 0.01$) and multiple blood product transfusion (odds ratio = 5 [2–17]; $P = 0.03$) were associated with an increased risk of occurrence of ARDS. The discrimination of the model was acceptable with an area under the curve of 0.75 [0.61–0.90] ($P = 0.001$). The percentage of adequately classified patients was of 88%.

We next compared the patients with unilateral and bilateral contusion. At 6 months, abnormal PFT results were found in 17 patients (65%) with bilateral contusion, as compared with 22 patients (75%) with unilateral contusion ($P = 0.5$). With regard to the self-administered St. George's Respiratory Questionnaire, the total score did not differ between the patients with bilateral pulmonary contusion and those with unilateral pulmonary contusion (19 [3–20] *vs.* 13 [2–24]; $P = 0.4$). The percentage of patients with a Karnofsky Performance Status below 80 was similar in both groups (54% *vs.* 37%; $P = 0.25$). The 6-min walk distance resulted in a restricted distance for 14 patients (82%) with bilateral pulmonary contusion, as compared with 15 patients (65%) with unilateral pulmonary contusion ($P = 0.3$).

Relations between Patients' Characteristics and Outcomes at 6 Months

We searched for predictors of an abnormal PFT result 6 months after discharge from the ICU. The results of univariate analysis showed that abnormal PFT results were more frequent in the patients with hemothorax and a Pao_2/Fio_2 ratio less than 200 at ICU admission. In the multivariate analysis, a Pao_2/Fio_2 ratio less than 200 was associated with an increased risk (odds ratio = 8 [2–41]; $P = 0.01$, $R^2 = 0.2$) of an impairment on PFT at 6 months. Of note, multiple rib fractures, smoking status, and duration of stay in the ICU were also entered in the model, but they did not significantly affect this outcome. Using a receiver operating characteristic curve analysis, we determined that the discrimination of the model was of 71% (56–85%) ($P = 0.01$). Sixty-four percent of the patients were adequately classified, with a cutoff of 0.74 providing the best sensitivity and specificity. This threshold was associated with a sensitivity of 54%, a specificity of 88%, a positive predictive value of 91%, and a negative predictive value of 44%. The risk of having impairment on PFT at 6 months was 91% for the patients with a Pao_2/Fio_2 ratio less than 200 at ICU admission, as compared with 56% for those with a Pao_2/Fio_2 ratio of 200 or greater.

One-year Follow-up

Paired comparisons were performed in 38 patients who underwent a second assessment 1 yr after discharge from the ICU. The dropout population did not differ significantly from the remaining cohort at 12 months. Among PFT, for these 38 patients including those with normal pulmonary function, FVC enhanced from a median of 84% [72–97%] at 6 months to 86% [77–99%] at the 1-yr follow-up ($P = 0.02$). The weight of these patients increased from a median of 68 [60–75] kg at 6 months to 71 [62–80] kg at the 1-yr follow-up ($P < 0.001$). The 6-min walk distance did not change significantly ($P = 0.09$). The St. George's Respiratory Questionnaire scores remained also unchanged between the two assessments ($P = 0.3$). Between the two assessments, the Karnofsky Performance Status increased significantly ($P = 0.002$), although it remained lower than that collected in the preinjury status ($P < 0.001$).

Discussion

Survivors of MTBCT have functional limitation 6 months after being discharged from the ICU as assessed by PFT and the 6-min walk distance. The St. George's Respiratory Questionnaire results suggest that pulmonary function limitation impacts quality of life. In contrast, no major pathologic images were found on chest CT scans.

To the best of our knowledge, this is the first study reporting with accuracy the respiratory outcome of a

population of MTBCT patients. In a previous study, the pulmonary-specific quality of life assessed by St. George's Respiratory Questionnaire, but not PFT, was reported for a population of trauma patients.[3] In this article, the St. George's Respiratory Questionnaire score of trauma patients without ARDS was 9, which is in full agreement with our results. Of note, in contrast to our study, this previous article investigated all types of trauma patients, not only those with blunt chest trauma.[3] The strength of our study is that all the patients underwent face-to-face interviews, PFT, and chest CT scanning at 6 months. In addition, a subgroup of patients was explored at 1 yr. All of these investigations were performed by the same group of senior physicians to reduce interobserver variations. Hence, our methodologic process ensured a good consistency of our results.

The pulmonary contusion was found to be the chief etiology of pulmonary dysfunction after blunt chest trauma.[27–29] In a previous matched–paired, case–control study, we concluded that pulmonary contusion alters gas exchange but does not seem to increase the morbidity and mortality of multiple trauma patients with head trauma.[27] To elucidate the impact of this specific injury in our cohort, the patients who had bilateral pulmonary contusions were compared with those who had unilateral pulmonary contusion. Bilateral contusions were associated with an increased risk of development of ARDS. This finding confirms a landmark study, showing that the extent of contusion volumes allows identification of patients at high risk of ARDS.[28]

At 6 months, our findings show the absence of difference between the patients with unilateral or bilateral pulmonary contusions. The rate of patients with an abnormal PFT result is independent of the bilateral feature of the contusion. In a previous study, pulmonary function was evaluated using spirometry and chest CT scans in 18 patients with blunt chest trauma for 6 months.[29] Functional residual capacity remained reduced throughout the 6 months in the 12 patients with pulmonary contusion. Fibrous changes were reported in the contused lung. These results are not found in the current study. However, in this previous investigation, the chest injuries were more pronounced than in the current study. The patients had to have an abbreviated injury scale score of 4 or 5 to be included. All of the patients with pulmonary contusion underwent mechanical ventilation and chest drainage. In our population, chest trauma was associated with head injury in the majority of patients. One can note that the severity of head trauma is known as a major predictor for poor outcome. Even after a mild head injury, a substantial proportion of patients still report problems 1 yr after injury.[30] In addition, the extracranial injuries may worsen the outcomes of patient with mild head trauma.[31,32] Hence, it is likely that the impaired quality of life and disability 6 months after discharge from the ICU in our cohort is multifactorial with a significant role of head injury.

One can note that the reported cohort is in a tight band of age. Previous studies have shown that elderly patients who sustain blunt chest trauma with rib fractures have twice the mortality and thoracic morbidity of younger patients with similar injuries.[33] The severity is directly related to a defect of the ventilatory system, because FVC could predict the duration of stay in elderly patients with rib fractures.[34] In our cohort, we included only multiple trauma patients who survived after discharge from the ICU. Because of these inclusion criteria, only three patients were older than 60 yr. Hence, the impact of age on the respiratory outcomes cannot be satisfactorily identified.

At 6 months, 70% of patients had impairment on PFT. An obstructive pattern was observed in nearly half of the patients. Hence, the obstructive pattern seems overrepresented as compared with the age- and sex-matched reference population.[35] Accordingly, the residual volume/TLC ratio was increased and the FEV_1/FVC ratio was decreased in these patients. Importantly, although 27% of the patients were smokers before admission, it seems unlikely that our population had an obstructive disease before the ICU admission, because smoking was not found as a predictor for obstructive pattern in our cohort. In addition, most of these patients were young. An obstructive pattern was still observed 1 yr after discharge from the ICU. We have no clear explanation for the increased incidence of obstructive pattern in our population. However, the respiratory dysfunction was probably related to a mechanical cause rather than a central cause because, despite a relative reduction of FVC, alveolar hypoventilation remained infrequent in our cohort of patients. Our population included a large number of patients with head trauma. One hypothesis would be that head trauma has a role on the obstructive pattern occurrence. Although a previous study demonstrated that isolated head injury reduced the TLC and FEV by 25–40%,[26] we did not find that head injury was a predictor for an abnormal PFT result. Only a Pa_{O_2}/F_{IO_2} ratio less than 200 at admission predicted, with a specificity of 88% and a positive predictive value of 91%, the occurrence of an abnormal PFT result at 6 months.

In our opinion, special attention should be paid to the assessment of the FVC. FVC was reduced in approximately 30% of our cases. FVC can be affected by several factors, including those causing limitation in chest mobility (e.g., pain, asthenia, muscle weakness, pleural sequel, rib cage deformation, ankylosis). However, the obstructive pattern and increased residual gas volumes can be also responsible for this alteration. Because FVC represents the volume that a patient is likely to mobilize during efforts, it is not surprising that reduced FVC corroborated with dyspnea during exercise as illustrated by the New York Heart Association Classification score

and the symptom domain of St. George's Respiratory Questionnaire in our population, even in the absence of reduced TLC. Indeed, the New York Heart Association Classification scores were above I in 72% of our cohort at 6 months and 65% at 1 yr, whereas only 12% of the patients retrospectively reported a score above I in the preinjury status.

Only 72% of the patients were able to walk at 6 months. This reflects the severity of injuries in this MT-BCT population. The walked distance was only 53% of the predicted value,[11] which is lower than the values reported in the patients with ARDS.[1] The distance increased by only 5% at the 1-yr evaluation. This limited advance in physical status corroborated with the reduced lung-specific health-related quality-of-life questionnaire reflected by the activity domain of St. George's Respiratory Questionnaire. One should note that among the activities, items related to moderate efforts such as walking up hills, carrying things up stairs, light gardening, or light sports were altered in most patients. This was also confirmed by the Karnofsky Performance Status, which reached a maximal value of 80 in 70% of our population at 6 months. It is important to mention that such a score was not found in the preinjury status.

A 4-point change on St. George's Respiratory Questionnaire has been determined to be a clinically meaningful difference.[36] In our population, the activity domain decreased from 17 at 6 months to 10 at 1 yr ($P = 0.3$). Such a decrease, even though it was not statistically significant, may reflect a clinical improvement in our patients. This alteration can be related to the enhancement of the Karnofsky Performance Status assessed at 1 yr.[15] This score attempts to measure the more "subjective" side of the outcome of the patients. Hence, this subjective improvement may be due to small but consistent clinical advances.

The current study has several limitations. Although our results demonstrate an association between chest trauma and outcomes, a proof of causality cannot be identified. A control group of patients would have permitted us to delineate the specific impact of chest trauma on the pulmonary outcomes. Indeed, during the ICU stay, interventions such as the ventilation mode[37,38] or events such as the occurrence of pneumonia[39] may have affected respiratory outcomes. After discharge from the ICU, one can speculate that only the most motivated patients were enrolled in the current study. Among the six patients who declined consent, four of them were unmotivated to perform the PFT adequately. Similarly, an orthopedic injury preventing active exercise may have altered the respiratory outcomes. In specific fields, like the comparisons of the patients with unilateral *versus* bilateral pulmonary contusions, the power of the study may be inadequate to provide the best responses. Indeed, the use of a small sample size can impair the results of our multivariate analysis. However, it is well

known that cohort studies should serve to generate hypotheses for designing controlled trials.

In conclusion, preinjury status, severity at admission, characteristics of the ICU stay, and chest CT scanning were unable to predict the impaired pulmonary function. This suggests that any patient with MTBCT is at risk of pulmonary morbidity. However, a Pa_{O_2}/F_{IO_2} ratio less than 200 at admission may determine the patients at high risk of pulmonary complications. These results should motivate physicians to perform early screening of the respiratory function in their trauma patients with chest injury. The impact of early intervention such as specific physiotherapeutic program on the respiratory outcome should be evaluated in future studies.

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