Acta Radiologica Open
7(6) 1–7

DOI: 10.1177/2058460118781419
journals.sagepub.com/home/arr
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Impact of donor chest radiography on clinical outcome after lung transplantation

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Abstract

Background: Organ donation guidelines recommend a "clear" conventional bedside chest radiograph before lung transplantation despite only moderate accuracy for cardiopulmonary abnormalities.

Purpose: To evaluate the influence of donor image interpretation on lung transplantation outcome in recipients by following early and late complications, one-year survival, and to correlate imaging findings and blood gas analysis with lung transplantation outcome in recipients.

Material and Methods: In 35 lung donors from a single institution clinical reports and study reviews of imaging findings of the mandatory bedside chest radiographs and blood gas analyses were compared with clinical outcome in 38 recipients. Hospitalization time, peri- and postoperative complications, early complications (primary graft dysfunction, infection), 30-day and one-year survival, and forced expiratory volume in 1 s percentage of predicted normal value (FEV1%) at one-year follow-up were analyzed.

Results: Findings in clinical reports and study reviews differed substantially, e.g. regarding reported decompensation, edema, infection, and atelectasis. No correlation was shown between imaging findings in clinical report or study review and blood gas analyses in the lung donors compared to postoperative outcome in recipients.

Conclusion: The interpretation of the mandatory chest radiograph in its present form does not influence one-year outcome in lung transplantation. Larger imaging studies or a change in clinical routine including computed tomography may provide evidence for future guidelines.

Keywords
Heart–lung transplantation, radiography, computed tomography, lung donor, organ procurement

Date received: 28 July 2017; accepted: 11 May 2018

Introduction

Lung transplantation is the only successful treatment option for patients with end-stage lung disease and has an approximately 80% one-year survival rate (1). International lung transplant donor criteria regarding imaging for lungs (2) are unprecise in the absence of adequate data and fail to provide firm guidelines regarding utilization of donor organs with abnormal chest radiographs. To advocate a "clear" conventional bedside chest radiograph together with required clinical parameters before proceeding to transplantation (2) necessitates some considerations from an imaging

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point of view. The accuracy of bedside chest radiography is high for detecting tubes and devices but only moderate for visualization and differentiation of opacities caused by cardiopulmonary abnormalities (3). Yet, cardiopulmonary abnormalities such as pulmonary edema, underlying pneumonia or aspiration, emphysema due to previous smoking, and traumatic lesions with parenchymal bleeding may all have an impact on the transplantation outcome. Substantial underdiagnosis in bedside radiographs in intensive care unit (ICU) patients has been reported, e.g. regarding aspiration, pleural effusion, and occult pneumothorax (4–7). Chest computed tomography (CT) has proven to have a high clinical impact (8) and, in contrast to chest radiography, also allows a more definitive evaluation of the size of the lungs (9), their bronchi, and anatomic variations (10), all of interest in matching donor and recipient in the preoperative work-up. As a consequence of the accumulated knowledge and experience, chest CT has been suggested as a complement to bedside chest radiography for better donor organ evaluation (11). However, at present, the vast majority of lung donors are still evaluated with bedside chest radiography and only a minority are examined with chest CT; in a previous study at the authors' institution, about 14% (12). After lung transplantation patients are closely monitored with high-resolution CT (HRCT) or CT, repeated bronchoscopies, and spirometry. HRCT based on 1 mm or thinner sections can detect subtle parenchymal lung changes (13–16), even if clinically occult (17), and is together with chest CT indispensable in the evaluation of possible lung complications after transplantation (18).

The aim of the current study was to evaluate the influence of the quality of donor image interpretation on lung transplantation outcome in recipients by following up early and late complications and survival during the first year; furthermore, to correlate pretransplant donor lung imaging findings and blood gas analysis with lung transplantation outcome in lung transplantation recipients.

Material and Methods

The current retrospective study was approved by the local Ethical Board (2016/2). Lung donors from Skåne University Hospital, Lund, Sweden during the period 2007–2014 were included.

Donor data

All organ donors including lung donors during eight years from one of two national lung transplantation centers were identified from a previous study. From that study, only the organ donors that actually donated the lung for transplantation were included in the current study and the data on imaging and reporting of the mandatory bedside chest radiography for lung evaluation prior to proceeding to donation on these patients were obtained. The mandatory chest X-ray was performed after brain death had been diagnosed according to the law together with consensus for proceeding to donation examination. It was clearly stated in the request that the patient was a potential lung donor and that the lungs should be evaluated for donation. A questionnaire for study scoring of the primary reports and radiographs had been created in collaboration with transplantation surgeons, containing clinical and donation relevant criteria. For scoring, imaging terms had been defined according to the Fleischner Society glossary of terms for thoracic imaging (19). Opacities, decompensation, pulmonary edema, infectious lung diseases, and aspiration were scored as absent, mild, moderate, or severe. First the clinical reports and then the bedside chest radiographs were analyzed by two chest radiologists in consensus, filling in the questionnaires during the same session, without knowledge about possible organ donation (12). The blood gas analysis for donor evaluation was retrieved from the medical records by the local transplantation team.

Recipient data

Information about the 38 anonymized recipients was gathered from organizations providing patient-oriented allocation and cross-border exchange of deceased donor organs with follow-up registers for the geographical areas of interest: Scandiatransplant for Scandinavia and Eurotransplant for Northern Europe. Available data included 30-day and one-year survival, hospitalization time due to transplantation, operative and postoperative complications and early complications such as primary graft dysfunction (PGD), infection and percentage of predicted normal value of forced expiratory volume in 1 s (FEV_1%) at the one-year follow-up. Spirometry as a screening test for general respiratory health, standardized since the 1980s (20,21) was regularly performed to monitor bronchiolitis obliterans (22). $FEV_1\% \leq 80\%$ of predicted FEV_1% was considered as lung function impairment (22,23).

Data analysis and statistics

Donor age, number, and scoring of pulmonary findings at clinical image reading and study review were recorded together with a radiographic diagnosis of aspiration or infection. Arterial blood gas analysis for PaO_2 measured after 5 min on 100% O_2 ventilation with positive end-expiratory pressure (PEEP) of 5 cm H_2O, pH, and location of the nasogastric tube were compared

with the outcome parameters 30-day and one-year survival. Early complications, infection, duration of hospitalization time due to transplantation, and FEV_1% at the one-year follow-up were also recorded. To evaluate possible significant correlations, two-tailed Pearson correlations were performed in SPSS version 23. After a Bonferroni correction for multiple correlations, a P value <0.0033 was considered statistically significant.

Results

Lungs from 35 donors were transplanted to 38 recipients, 30 of whom had a double lung transplantation, one had a combined heart and double lung transplantation, and seven had a single lung transplantation. Recipients were from Scandinavia (n = 35) and northern Europe (n = 3). Mean age of 35 donors (20 women, 15 men) was 45 years (age range = 6–71 years, SD 19.1). Seventeen donors fulfilled extended donor criteria (24). The transplantations were performed during 2007–2014 with a mean number of four transplantations per year (range = 2–8). The mean age of the 38 recipients (24 women, 14 men) was 48 years (age range = 15–64 years, SD 14.5).

Clinical and imaging data of donors

Blood gas analysis results are presented in Table 1. The conventional chest radiography was without pathologic lung findings or misplaced tubes according to the clinical reports in 14 of 35 donors, while only eight of these were normal at study review. Further, 27 pulmonary findings were reported clinically in 18 donors compared with 67 findings at study review in 27 donors (Table 2). In the clinical report, five donors were diagnosed with decompensation or edema and one with aspiration or infection (Figs. 1 and 2). The corresponding figures for study review were 19 and seven, respectively. Out of 18 donors with atelectasis at the study review, 15 represented atelectasis in the left lower lobe. While in the clinical report only two out of 33 nasogastric tubes were found to be in an incorrect position, this number increased to ten at study review (Table 2).

Table 1. Arterial blood gas analysis for 35 donors. PaO_2 was measured after 5 min on 100% O_2 ventilation with positive end-expiratory pressure (PEEP) of 5 cm H_2O.

	Mean	Min	Max	SD	Normal range
PaO_2 (mmHg)	59.0	32.2	74.2	9.8	80–100
pH	7.4	7.2	7.5	0.06	7.35–7.45

Outcome data for recipients

Three recipients died during the first 30 days from perioperative complications (n = 2) and multi-organ failure (n = 1). One additional recipient died during the first year from B-cell lymphoma. Thus 30-day and one-year survival were 92% and 89%, respectively.

Table 2. Findings in 35 mandatory chest radiographs in 35 donors (15 of 18 cases of atelectasis at study review were left lower lobe atelectasis).

	Findings (n)	
	Clinical report	Study review
Incorrect tracheal tube	2	5
Incorrect CVC	1	2
Incorrect NGT	2	10
Decompensation	3	15
Edema	2	4
Aspiration or infection	1	7
Atelectasis	12	18
Pleural effusion	3	4
Unclear rounded opacity	0	1
Unclear finding in a rib	1	1
Total number of findings	27	67
Normal examinations (n)	14	8

CVC, central venous catheter; NGT, nasogastric tube.

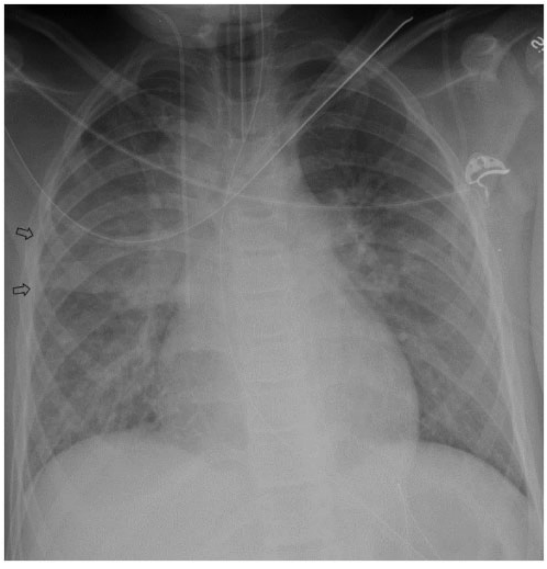

Fig. 1. Bedside chest radiograph showing loss of definition of vessels and hilar structures with ground-glass opacities in keeping with moderate pulmonary edema which was reported. There is also a more pronounced opacity in the basal part of the right upper lobe (arrows) that seems to respect the anatomical borders raising the suspicion of segmental pneumonia that was not reported at the primary reading.

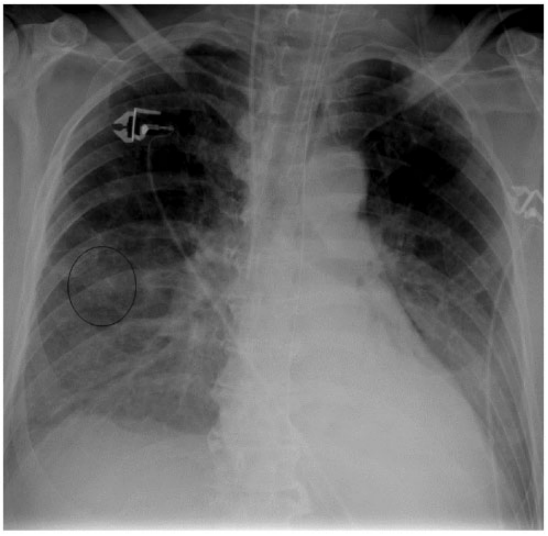

Fig. 2. Bedside chest radiograph showing an atelectasis of the left lower lobe with an air bronchogram which was reported at the primary reading. The unclear finding of a subtle rounded opacity with a diameter of approximately 1.5 cm on the right side (circle) was not reported.

In the 28 recipients of double lung transplantation surviving the first year post transplantation, the median FEV_1% was 80% (range = 46–144%), i.e. representing slightly impaired lung function. For the six surviving single lung recipients, median FEV_1% was 52% (range = 35–94%).

In 36 patients surviving the perioperative phase, early complications consisted of 18 cases of infection (nine pulmonary and nine extra-pulmonary infections) and one case of primary graft dysfunction. Seven patients had other complications (impairment of kidney function, suspicion of rejection, necrosis in the bronchial anastomosis, tracheostomy, brain ischemia, and ileus). Detailed donor and recipient data are presented in Supplementary Table 1. Correlations were performed with 30-day and one-year survival, hospitalization time, infectious or other complications, and FEV_1% at the one-year follow-up as outcome measures in lung recipients compared with pulmonary complications in lung donors such as decompensation/edema, infection or aspiration, location of the nasogastric tube, and arterial pO_2 and pH. No correlations were found. No statistically significant differences in prognostication of transplantation outcome could be shown between the clinical interpretation and study review of the mandatory chest radiography.

Discussion

In the current retrospective study in a patient cohort of 35 lung donors and 38 lung recipients (seven single and 31 double lung transplantations), the one-year survival rate was 89% which is similar to or slightly better than international figures (1). Out of 35 chest radiographs, 40% were normal without findings or misplaced tubes in the clinical report, but only 23% at study review. These are far lower rates than in a previous study analyzing donors where 82% of chest radiographs were considered normal (25). In that study, however, tubes were not accounted for, and, if excluding the misplaced tubes, 40% in our material were normal. Also, the median age was far lower (28.8 years, SD 13.4). In the current study, in 18 donors with atelectasis at the study review, 15 represented atelectasis in the left lower lobe, a common finding in supine patients. One of the donors was a small child. The examination was in both the clinical review and the study report reviewed in keeping with the established interpretation of pediatric chest X-rays (26).

To our knowledge correlations between donor imaging and lung recipient outcome has not been studied before. Clinically established donor-related risk factors for PGD (27) are smoking history, aspiration pneumonia, trauma, and hemodynamic instability. The hypothesis in the current study was that lung transplantation outcome would correlate with imaging findings of those entities, or to the presence or absence of findings in general in donors who met the donor acceptability criteria (2) or were extended criteria donors (24). During the one-year observation period, no correlations were found between donor imaging findings in the clinical report, study review, or blood gas analyses and outcome parameters for the recipients. This could be due to the small patient cohort or the complexity of factors influencing the possible outcome in both donor and recipient. The outcome parameters in the current study are, however, comparatively coarse, and systematic data for analysis of, for example, the number of bronchoscopies performed or the need for bronchial stenting, postoperative supportive therapy, or post-transplant immunosuppression regime were not available. What impact information gained from imaging regarding pre-existing or acquired donor variables, e.g. emphysema, decompensation, or infection, might have is not known. Since the long-term survival after lung transplantation is among the shortest of all solid organ transplantation (28), it would be of interest to identify causes for it.

The results in the current study also indicate that bedside chest radiography in its present form, being the imaging method least accurate for detecting cardiopulmonary abnormalities even if interpreted focusing on aspects relevant for donation, does not have a clinically significant impact on one-year outcome in recipients. However, it probably rules out some of the gross pathologies before donor acceptance. It is worth noting that the image analysis in donor assessment often relies

on transplantation physicians (29,30), surgeons (31), or the organ procurement coordinator (32) without direct involvement of radiologists. Nonetheless, in a previous study from the authors' institution, imaging in potential organ donors and its clinical relevance was analyzed (12) showing that important information regarding donor recipient matching, operative planning, and important information for the transplantation as such could be gained by a structured analysis of already available imaging studies from a donation point of view. Imaging findings in the subgroup of donors reported in the current study are similar to the findings reported for the entire cohort (12). Also, CT, completely or incompletely including the chest, offers additional information of value for the transplantation (12). Therefore, a larger study including more donors using CT for imaging and involving radiologists would be of interest. The donor pool is expanding, moving away from the original donor criteria towards expanded donor criteria (24,33) which now represents about half of the donor pool (34) and coincides with the peak age for lung cancer (35) and lung fibrosis (36). In addition, donation nowadays takes place not only after brain death but also after cardiac death (37). Thus, improved imaging might be beneficial and chest CT, although not mandatory, is nowadays increasingly used in the pre-transplant setting. More advanced imaging such as chest CT contributes supplementary information that could potentially have an impact on the outcome, such as highlighting technical challenges in patients with previous lung or heart surgery (38) and help with identification of anatomical structures and their measurements in living lung donors (39,40). Several studies have evaluated lung volume assessed by CT on non-transplant patients, and successfully compared the results with lung capacity results from lung function tests, indicating that CT volume measurements are better than those based on demographic data or radiography (41–43). However, a perusal of the literature has not revealed any reports on systematic evaluation of lung donors with chest CT.

Due to its sensitivity, CT can certainly disqualify some donors from proceeding to donation, thereby decreasing the donor pool but it will probably include others that at present are classified as marginal donors. In a broader and legal perspective, no pre-explantation examination is allowed before a diagnosis of brain death followed by a 24-h window for organ evaluation and explanation. The organ donor is most often a general organ donor with the need for evaluation of all potentially useful organs (e.g. heart, lung, liver, kidneys, and pancreas) by different transplantation teams requiring information from different imaging methods such as chest radiography, hepatic CT, and conventional coronary angiography. Perhaps a combined thoracic, cardiac, and abdominal CT using a reduced amount of contrast medium with a protocol for low glomerular filtration (GFR) could be used to save time and increase the information content. The low GFR protocol would serve to reduce the impact of intravenous contrast on the kidney preserving the renal function before kidney transplantation. The examination should preferably be interpreted with the help of a standardized questionnaire to raise awareness about donor-specific findings. Previous smoking and aspiration are linked to PGD, but this is not commonly known among radiologists; however, donor-relevant findings of emphysema or aspiration are easily noted on CT by all radiologists, if aware that these entities are particularly important.

The discrepancy in number and severity of findings between two readings in the current study, and even so in the larger study from which those data are collected, indicates a substantial observer variation. This has been reported previously (2) where the paucity of data regarding the degree of observer variation has prevented the design of firm guidelines regarding how to interpret radiographic findings in a transplant setting.

Limitations of the current study is the small number of donors from a single institution and the limited follow-up data in the recipients. However, the available data are limited by what data the transplantation agencies record.

In conclusion, the mandatory blood gas analysis and interpretation of imaging findings in the chest radiograph before lung donation in its present form did not show any influence on the one-year outcome after lung transplantation. Larger imaging studies or a change in clinical routine including CT may provide evidence for future guidelines.

Acknowledgements

We thank Stig Steen and Trygve Sjöberg for help with the study design, Scandiatransplant and Eurotransplant for help with data collection, especially Eva Marie Braf, Fatma Bergquist and Marie Omnell Persson. We also thank Are Martin Holm for help with data collection and interpretation.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Supplementary material

Supplementary material is available for this article online.

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