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(F)utility of computed tomography of the chest in the presence of pleural effusion

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Abstract

Background: Pleural effusion is common and can cause significant morbidity. The chest X-ray is often the initial radiological test, but additional tests may be required to reduce uncertainty and to provide additional diagnostic information. However, additional exposure and unnecessary costs should be prevented. The objective of the study was to assess the clinical benefit of an additional chest computed tomography (CT) scan over plain chest X-ray alone in the management of patients with pleural effusion.

Methods: Retrospective analysis in 94 consecutive patients with pleural effusion who underwent chest X-ray and CT scan over an 18-month period in a single institution. All chest X-ray and CT scan reports were compared and correlated with clinical parameters in order to assess their utility in the clinical management. No blinding was applied.

Results: In 75 chest CT scan reports (80%), information provided by the radiologist did not change clinical management when compared to plain chest X-ray alone and did not provide any additional information over chest X-ray. Only 2/49 (4%) of the native chest CT scan reports provided clinically relevant information as compared to 17/45 (38%) contrast-enhanced chest CT scan reports ($p < 0.001$).

Conclusions: In this retrospective cohort of patients with pleural effusion, an additional chest CT scan was not useful in the majority of patients. However, if a chest CT scan is required, then a contrast-enhanced study after pleural aspiration should be performed. Further prospective studies are required to confirm these findings.

Keywords: computed tomography, cost-effectiveness, imaging, pleural effusion, radiation exposure

Introduction

Pleural effusion, a pathologic accumulation of fluid in the pleural cavity, is common and a significant cause of morbidity [1]. Normally, the pleural cavity contains a small amount of serous fluid (5–10 mL) [2] which allows the smooth movement between the visceral and parietal pleura. An imbalance between the secretion and reabsorption of the fluid within the pleural cavity results in its accumulation (pleural effusion) and can occur due to various causes, the most common being malignant neoplasia, congestive heart failure pneumonia, cirrhosis, and tuberculosis [3, 4].

It is important to define the type of effusion and the underlying cause in order to effectively manage the individual patient. It can be either transudative or exudative based on fluid analysis using Light criteria [2, 5, 6]. This differentiation helps narrow the underlying process and guides further investigation(s) and treatment [5]. For instance, transudative effusion is mainly caused by increased hydrostatic pressure and/or decreased oncotic pressure and is often the result of a systemic process such as congestive heart failure, cirrhosis of the liver, or nephrotic syndrome. In contrast, exudative effusion is primarily due to the increased permeability of the capillary bed due to an inflammatory or neoplastic process involving the pleura and/or lung parenchyma [7]. Pneumonia, tuberculosis, and cancer are the common causes of exudative effusion [8].

Differential diagnoses are wide-ranging; therefore, cost-effective, systematic approaches in the diagnosis of an underlying cause are important. Chest X-rays, ultrasound, and computed tomography (CT) scans are often used to confirm suspected clinical findings. The purpose of additional testing is to reduce the uncertainty and to provide useful diagnostic information that helps in reaching the correct diagnosis efficiently and safely. Timely, safe, and cost-effective approaches to establishing the underlying cause of pleural effusion are important and guidelines are available [5, 9]. However, the management

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of pleural effusion in clinical practice is heterogeneous [8] and though guidelines recommend analysis of the pleural fluid before advanced imaging [10]. CT of the chest is often performed before aspiration of the pleural fluid in clinical practice, when analysis of the pleural fluid is actually more important in guiding further management of individuals with pleural effusion.

Effective utilization of resources and cost of care are secondary issues but are equally important and need to be considered in the current health care environment when resources are finite. Similarly, exposure to radiation is an important safety measure and must be considered when requesting imaging studies, including CT scans [11, 12], especially when it may not provide additional information over other investigations to change management.

To our knowledge, no prior studies have evaluated the utility (or futility) of chest CT scans in the presence of pleural effusion. We conducted this study specifically to answer this question.

Materials and methods

We conducted a retrospective analysis of the reports of the imaging studies performed on patients with a new diagnosis of pleural effusion between 1st June 2014 and 31st December 2015 at Timmins and District Hospital, Ontario, Canada. Only written reports of the imaging studies were assessed and individual films were not reviewed or reread. All CT scans were performed using a Toshiba Aquilion 64 scanner (Toshiba Medical Systems Corporation, Tustin, CA, USA). Those who had pleural aspiration before a chest CT as per guidelines were excluded. The local Ethics Committee at the hospital approved the study. Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA) version 16.0, and the χ^2 -test was performed on the additional information reported on contrast-enhanced versus non-enhanced chest CT reports compared to chest X-ray reports. The statistically defined significance level was 0.05.

Results

A total of 3284 chest CT scans were performed during the study period for various indications. Of these, a total of 111 patients had a new diagnosis of pleural effusion on chest X-ray and chest CT scan. Of these, 17 patients had pleural fluid aspiration as per guidelines and were excluded from this study. Ninety-four (84.6 %) individuals who had chest CT before aspiration of the pleural fluid (Figure 1) were included in this study. The mean age was 69.84 years (range 24–97) with 77 % of individuals being over the age of 60, and 50 (53.2 %) were males. Of these 94 individuals, 55 (58.5 %) had hypertension, 39 (41.5 %) had a history of ischemic heart disease or congestive heart failure, and 23 (24.5 %) and 11 (11.7 %) had diabetes mellitus and chronic kidney disease, respectively (Table 1).

Of the 94 chest CT scans, 49 were non-contrast and 45 were contrast-enhanced studies. Forty-seven (96 %) of the 49 non-contrast chest CTs did not provide any clinically significant information beyond the chest X-ray (Table 2) that would have altered the management. Only 2 of the 49 non-contrast chest CTs provided additional information, suggesting a neoplastic process (one with hilar and mediastinal lymphadenopathy and the other showing bilateral pulmonary nodules with hilar and mediastinal lymphadenopathy). Seventeen (37.8 %) of the 45 contrast-enhanced CT scans showed clinically significant information (Table 3).

Discussion

Imaging studies play a pivotal role in the diagnosis and management of pleural disease, and chest CT is frequently used to investigate thoracic pathologies because

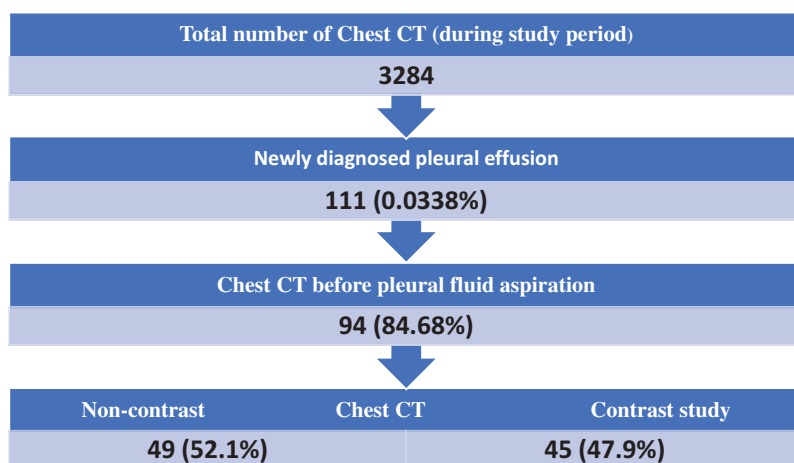


Figure 1: Selection of study population.

Table 1: Demographics.

Patient characteristics	Number (%) (n=94)
Age, years	69.8 (Range: 27–94)
> 60 years	72 (76.8)
< 60 years	22 (23.2)
Gender	
Male	50 (53.2)
Comorbidities	
Hypertension	55 (58.5)
Ischemic heart disease/Congestive heart failure	39 (41.5)
Diabetes	23 (24.5)
Chronic kidney disease	11 (11.7)

of its cross-sectional perspective and superior contrast resolution [13] and is often considered the gold standard as it is better at differentiating pleural from parenchymal disease [14]. However, the non-contrast chest CT in the presence of pleural effusion often confirms pleural effusion and shows the underlying collapsed lung and rarely provides additional information [15] over chest X-ray. In our study, 47 of 49 (95.9%) non-contrast studies did not provide a clinically significant or relevant finding beyond a chest X-ray that would have helped clarify the underlying process. Simpson and Hartrick concluded that 68% of analyzed chest CT scans were inappropriate in their study [15]. Similarly, the Canadian Association of Radiologists noted that “as many as 30% CT scans and other imaging procedures are inappropriate or contributing no useful information” [16].

The contrast-enhanced chest CT is useful in the management of patients with suspected malignant effusion [17], but is poor in differentiating empyema from parapneumonic effusions [7]. The important aspect of the chest CT scan is not only to detect pathology in the pleural cavity but also to define the associated pathology, if any, of the lung parenchyma and the presence or absence of hilar lymphadenopathy [6]. Contrast-enhanced chest CT is often used to enhance the pleural

and lung parenchymal lesion(s) in cases of pleural effusion. In this study, we found that pulmonary nodules, mediastinal, and/or hilar lymphadenopathy were the common findings on a contrast-enhanced chest CT that provided clinically significant information over non-contrast studies (38% vs. 4%; $p < 0.001$). A recent small retrospective analysis of the CT images of 32 patients with pleural effusion with pre- and post-drainage chest CT scans failed to provide an additional findings to change management; however, it is not clear whether these were contrast-enhanced studies or not [18]. Recent guidelines [10] also recommend a contrast-enhanced chest CT scan when analysis of pleural fluid failed to reveal the underlying cause.

The volume of pleural fluid can be estimated with a reasonable degree of accuracy with a chest X-ray and a posteroanterior view can detect over 200 mL of fluid in the pleural cavity, whereas a lateral view can detect as little as 50 mL of fluid [19]. Furthermore, the decubitus view of the chest X-ray can detect small amounts of free fluid and differentiate a free-floating from a loculated pleural effusion [20]. Compared to a chest X-ray and thoracic sonography, a chest CT scan is associated with relatively higher exposures of radiation [11] and additional costs to the patient or the healthcare system [15]. Thoracic sonography (USG) has been assessed in a recent study and was considered a useful diagnostic tool because of its low radiation exposure, cost-effectiveness, and noninvasiveness [21]. We have not assessed the role of thoracic ultrasound in this study, but the current availability of portable bedside ultrasound machines may improve its usefulness and application in clinical practice without increasing cost of care.

To our knowledge, no studies comparing the cost of different radiological tests are published in Canada, and the cost of the same study is variable in different parts of the United States. In Canada, though the cost to the patient is nil – being a universal healthcare, but cost to system of non-contrast chest CT scan [22]. The use of imaging tests has been rapidly increasing over the past decade, resulting in an exponential increase in imaging

Table 2: CT chest in pleural effusion – additional information compared to chest X-ray.

CT Chest: Type n=94	Additional information over chest X-ray		Significance (χ^2)
	Yes n=19 (20.2%)	No n=75 (79.8%)	
Non-contrast (n = 49)	2 (4.1%)	47 (95.9%)	(p = 0.0001)
Contrast (n = 45)	17 (37.8%)	28 (62.2%)	

Table 3: Comparison between chest x-ray and contrast-enhanced CT scan findings (based on Radiologist reports).

Number of cases	Chest X-ray reports	Contrast CT scan reports
1	Left pleural effusion associated with atelectasis	Left pleural effusion with pleural nodules
2	Left pleural effusion with diffuse opacification of left hemithorax, possible lymphadenopathy	Left pleural effusion with mediastinal and hilar lymphadenopathy
3	Left pleural effusion with bronchial thickening on the right	Left pleural effusion with conglomerate mediastinal lymphadenopathy
4	Left pleural effusion with collapse and consolidation	Complex loculated air fluid with collapse and consolidation
5	Bilateral pleural effusion with consolidation	Left pleural effusion with upper lobe mass and mediastinal lymphadenopathy
6	Bilateral pleural effusion with atelectasis	Right pleural effusion with subcarinal lymphadenopathy
7	Right pleural effusion with residual hydropneumothorax	Right pleural effusion with bilateral multiple pulmonary nodules
8	Right pleural effusion with patchy opacities	Right pleural effusion with hilar lymphadenopathy
9	Bilateral pleural effusion	Bilateral pleural effusion with pleural nodules
10	Right pleural effusion with bibasilar atelectasis	Right pleural effusion with multiple pleural nodules
11	Bilateral pleural effusion with basilar opacity and right upper lobe nodule	Bilateral pleural effusion with basal segmental atelectasis and calcified pleural plaques
12	Complete opacification on left hemithorax	Massive left pleural effusion with mediastinal and hilar lymphadenopathy
13	Right pleural effusion with hilar mass	Right pleural effusion with bilateral hilar lymphadenopathy
14	Bilateral pleural effusion with consolidation	Bilateral pleural effusion with upper lobe consolidation and hilar lymphadenopathy
15	Left pleural effusion with atelectasis, small pulmonary nodule on upper left lobe	Left pleural effusion with anterior mediastinal mass
16	Bilateral pleural effusion with atelectasis	Bilateral pleural effusion with subcarinal lymphadenopathy
17	Left pleural effusion with likely granulomas	Left pleural effusion with bilateral lymphadenopathy and pulmonary nodules

costs in Canada [16] and data from Canadian Institute for Health Information show that 4.4 million Canadians underwent a CT scan in 2011–2012 [23]. Selecting the appropriate test in the diagnostic pathway is paramount, and it not only provides useful information but also saves the costs of unnecessary tests. If we could eliminate inappropriate imaging even in a small number of individuals, it will have a significant impact on the health care system, not only in constraining cost but also in improving quality and patient safety [24].

CT, in addition to its cost, is one of the major sources of radiation exposure in medical imaging. In the recent years, the utilization of CT scans has rapidly increased in medical practice. In 1997, only 3% of radiological tests were CT scans but they were responsible for 20% of total radiation exposure and within a decade the radiation exposure attributed to CT scans has seen a 3-fold increase [25, 26]. Radiation exposure from a chest CT scan is considered minimal (8 mSv) but is still 400 times that of the radiation exposure from a chest X-ray (0.02 mSv) [27]. Cumulative radiation exposure is one of the emerging risk factors for the development of cancer [12]. In current medical practice, the exposure to radiation from

medical imaging is increasing despite its attributable risk. There is no doubt that increased use of CT has improved diagnostic and therapeutic abilities of the practicing clinicians and improved patient outcomes. However, this practice increases the radiation exposure of the individual patient over time, and this risk of radiation must be taken into consideration when ordering an imaging study during the evaluation of an individual patient [12].

The non-contrast chest CT in the presence of pleural effusion should be avoided because of its low diagnostic yield, risk of radiation exposure, and additional cost to the individual or the system. The analysis of the pleural aspirate should be performed before advanced imaging as per guidelines. If required, then a contrast-enhanced chest CT should be considered after careful assessment of the risk-benefit ratio and alternate options.

Limitation

Our study is limited as it is a retrospective and an observational study from a single center. Only the original reports by the reading radiologist(s) for all imaging

studies were assessed. The films were not reviewed to mimic real-life practice and to reduce confounding from the effect of hindsight. The scope of this observational study was limited to the (ab)use of chest CT in the presence of pleural effusion in real-life practice.

Conclusions

In the management of pleural effusion, a chest X-ray with decubitus view often provides sufficient information at minimal cost for its initial management. To effectively utilize resources and to avoid unnecessary radiation exposure, a chest CT should preferably be performed after aspiration of the pleural fluid as per guidelines, and when required, a contrast-enhanced study should then be performed. Further prospective studies are required to confirm these findings.

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References

- Medford A, Maskell N. Pleural effusion. *Postgrad Med* [Internet]. 2005;81:702–10. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16272233>. Accessed 30 Mar 2016.
- Yu H. Management of pleural effusion, empyema, and lung abscess. *Semin Intervent Radiol* 2011;28:75–86.
- Porcel JM, Esquerda A, Vives M, Bielsa S. Etiology of pleural effusions: Analysis of more than 3,000 consecutive thoracenteses. *Arch Bronconeumol* [English Edition] [Internet]. 2014;50:161–5. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S1579212914001025>.
- Light RW. Pleural Effusions. *Med Clin North Am* [Internet]. 2011;95:1055–70. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22032427>. Accessed 10 Jul 2017.
- Hooper C, Lee YC, Maskell N. Investigation of a unilateral pleural effusion in adults: British thoracic society pleural disease guideline 2010. *Thorax* [Internet]. 2010;65:ii4–17. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20696692>. Accessed 30 Mar 2016.
- Akulian J, Feller-Kopman D. The past, current and future of diagnosis and management of pleural disease. *J Thorac Dis* 2015;7:S329–38.
- Arenas-Jimenez J, Alonso-Charterina S, Sanchez-Paya J, Fernandez-Latorre F, Gil-Sanchez S, Lloret-Llorens M. Evaluation of CT findings for diagnosis of pleural effusions. *Eur Radiol* [Internet]. Springer-Verlag. 2000;10:681–90. Available at: <http://link.springer.com/10.1007/s003300050984>. Accessed 2 Apr 2016.
- Porcel JM, Statophoulos G, Lee YC. Advances and controversies in pleural diseases. *J Thorac Dis* 2015;7:961–3.
- McGrath EE, Anderson PB. Diagnosis of pleural effusion: A systematic approach. *Am J Crit Care* 2011;20:119–28.
- Hallifax RJ, Talwar A, Rahman NM. The role of computed tomography in assessing pleural malignancy prior to thoracoscopy. *Curr Opin Pulm Med* [Internet]. 2015;21:368–71. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26016581>. Accessed 30 Mar 2016.
- Sistrom CL, Dreyer KJ, Dang PP, Weilburg JB, Boland GW, Rosenthal DI, et al. Recommendations for additional imaging in radiology reports: Multifactorial analysis of 5.9 million examinations. *Radiology* 2009;253:453–61.
- Hansen J, Jurik AG. Analysis of current practice of CT examinations. *Acta Oncol (Madr)* [Internet]. 2009;48:295–301. Available at: <http://www.tandfonline.com/doi/full/10.1080/02841860802266714>.
- Turner MO, Mayo JR, Muller NL, Schulzer M, FitzGerald JM. The value of thoracic computed tomography scans in clinical diagnosis: A prospective study. *Can Respir J* 2006;13:311–16.
- Evans AL, Gleeson FV. Radiology in pleural disease: state of the art. *Respirology* 2004;9:300–12.
- Simpson G, Hartrick GS. Use of thoracic computed tomography by general practitioners. *Med J Aust* 2007;187:43–6.
- Dawson H. Family doctors and lower diagnostic imaging costs: How do we get there from here? *Médecins de famille et coûts d'imagerie diagnostique moins élevés : comment peut-on y arriver?* *Healthc POLICY* [Internet]. 2011;326. Available at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3107115/pdf/policy-06-032.pdf>. Accessed 24 Jul 2017.
- Traill ZC, Davies RJ, Gleeson FV. Thoracic computed tomography in patients with suspected malignant pleural effusions. *Clin Radiol* [Internet]. 2001;56:193–6. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/11247695>. Accessed 31 Mar 2016.
- Corcoran JP, Acton L, Ahmed A, Hallifax RJ, Psallidas I, Wrightson JM, et al. Diagnostic value of radiological imaging pre- and post-drainage of pleural effusions. *Respirology* [Internet]. 2016;21:392–5. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26545413>. Accessed 24 Apr 2016.
- Blackmore CC, Black WC, Dallas RV, Crow HC. Pleural fluid volume estimation: a chest radiograph prediction rule. *Acad Radiol* [Internet]. 1996;3:103–09. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8796649>. Accessed 11 Apr 2016.
- Saguil A, Wyrick K, Hallgren J. Diagnostic approach to pleural effusion. *Am Fam Physician* 2014;90:99–104.
- Tasci O, Hatipoglu ON, Cagli B, Ermis V. Sonography of the chest using linear-array versus sector transducers: Correlation with auscultation, chest radiography, and computed tomography. *J Clin Ultrasound* [Internet]. 2016. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26863904>. Accessed 9 Apr 2016.
- Canadian magnetic imaging (CMI): scans + rates [Internet]. Available at: <http://www.canmagnetic.com/scans-rates/>. Accessed 25 Jul 2017.

23. Executive Summary. Medical Imaging in Canada 2012. Cihl [Internet]. 2013;98. Available at: <http://www.cihl.ca/CIHI-ext-portal/pdf/internet/MI>.
24. Fraser J, Reed M. Appropriateness of imaging in Canada. Can Assoc Radiol J [Internet]. 2013;64:82–4. Available at: http://www.car.ca/files/Appropriateness_Imaging_Canada-Fraserj-201305.pdf. Accessed 24 Jul 2017.
25. Leswick DA, Syed NS, Dumaine CS, Lim HJ, Fladeland DA. Radiation dose from diagnostic computed tomography in saskatchewan. Can Assoc Radiol J [Internet]. Elsevier Inc. 2009; 60:71–8. DOI:<http://dx.doi.org/10.1016/j.carj.2009.02.035>.
26. Wiest PW, Locken JA, Heintz PH, Mettler FA. CT scanning: a major source of radiation exposure. Semin Ultrasound CT MR [Internet]. 2002;23:402–10. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12509110>. Accessed 15 Jun 2017.
27. Rehani M, Berry M. Radiation doses in computed tomography: the increasing doses of radiation need to be controlled. BMJ 2000;320:593–4.