PICTORIAL ESSAY

All B-lines are equal, but some B-lines are more equal than others

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Abstract
In this pictorial essay the theme of the differential diagnosis between the different causes of lung interstitial disease will be discussed, which can be detected on lung ultrasound as B lines. In particular, from the experience obtained during the covid-19 pandemic, the term B line may appear too simplified, and new data in the literature show that it is necessary to update the terminology and the differential diagnosis of this ultrasound sign.

Keywords Lung · B-line · Artifact · Pneumonia · Ultrasound

The SARS-CoV-2 pandemic enhanced the role of lung ultrasound [1–4]. Particularly, since SARS-CoV-2 induces an interstitial viral pneumonia affecting the peripheral areas of the lung (at least in the first phase), lung ultrasound proved to be a useful and easy to apply method by detecting subpleural lung changes, based on the detection of a specific sign of interstitial disease called B line [1–4].

The "official" definition of B line dates back to a consensus published in 2012, where they were defined as "laser-like vertical hyperechoic reverberation artifacts arising from the pleural line are called B-lines ("comet tails"), extending to the bottom of the screen without fading and moving synchronously with lung sliding" [5].

Several works and data in the literature have focused on the evaluation of B lines in cardiology field [6–9] (Fig. 1). Therefore, the B lines, as defined in the consensus, were proved to be a sign characterized by excellent statistical accuracy in the differential diagnosis of cardiogenic pulmonary edema in patients with dyspnoea and acute respiratory failure, in particular versus COPD [6]; they have also been shown to be useful in monitoring the clinical response to pharmacological and ventilation therapy (eg continuous positive airway pressure) [7–9]. Moreover, their use has also been tested as outpatient monitoring of patients with chronic heart failure [7–9].

In addition to cardiogenic pulmonary edema, the B lines can be found in other forms of non-cardiogenic, inflammatory pulmonary edema, ie acute respiratory distress syndrome (ARDS) [10]. The distribution of the B lines could distinguish cardiogenic pulmonary edema from ARDS; indeed, in cardiogenic edema there is a typical pulmonary base-apex gradient, whereas the distribution is typically irregular and non-homogeneous in patients with ARDS [10, 11].

Moreover, some works tested the usefulness of lung ultrasound in the diagnosis of chronic fibrosing interstitial diseases. The main signs of those diseases were the presence of B lines, but with specific features; indeed, they present a non-homogeneous distribution (variable according to the main pathology), the pleural line is irregular, thickened and often interrupted by small subpleural consolidations [12, 13]. Furthermore, B lines are more thickened and irregular than those found in cardiogenic pulmonary edema [12, 13] (Fig. 2).

A similar experience was performed on patients with rheumatic diseases, in which the execution of a lung ultrasound with detection of B lines, could show early lung involvement of the disease [14–16].

Furthermore, we must not forget focal interstitial syndrome such as contusion, bronchopneumonia and finally cancer [13].

The SARS-CoV-2 pandemic underlined the features of viral pneumonia: interstitium-alveolar pneumonia which can be detected by finding B lines, consolidations and in some rare cases pleural effusion on ultrasound [1–5]. In particular, SARS-CoV-2 pneumonia showed some specific features; the
pleural line is almost irregular, jagged, sometimes thickened and with small subcentimetric subpleural consolidations of a hypoechoic appearance [1–5].

Furthermore, the B lines have specific features not only in their distribution (irregular with saving areas) but also in their appearance: they are often different from each other, with a different ultrasound beam width; some of them do not reach the bottom of the image; some seem to have a more demarcated and hyperechoic internal layer (Figs. 3, 4, 5 and 6). Furthermore, some authors evaluated the sign of the so-called "light beam", ie that of an echogenic front (probably formed the confluent B lines) that appears and disappears with the acts of breath (Figs. 7, 8). According to a study conducted by Volpicelli and colleagues, this sign is a typical feature of the LUS pattern in COVID-19 pneumonia, and its presence during a pandemic surge should prompt high suspicion for COVID-19 pulmonary involvement [1].

In last years, some works attempted to find physical bases for the genesis of B lines. In particular, a first work by Mento et al. published in 2020 showed that B-lines can be clearly visualized only within a specific frequency range on an engineering model [17]. The frequency response of these bubbly structures is more likely associated to specific resonance phenomena. A subsequent work [18] by the same group tested the genesis of the artifacts on a laboratory model by reproducing the alveoli shape with the alveolar interstitium level, with known dimensions; the authors showed that low imaging frequencies (i.e., f 2 MHz) generally do not allow the generation of consistent artifacts, regardless of the alveolar diameter choice. Only when the alveolar spacing assumes the largest investigated value (i.e., s 395 lm) do the lowest frequencies start to enable the B-lines' formation.

Therefore, the final representation of the vertical artifact on B-mode ultrasound seems to strongly depend on the frequency of the ultrasounds employed by the probe (therefore on the setting of the machine), and on the three-dimensional
structure of the interstitium-alveolar spaces. The authors argued that those factors can affect the representation of the artifacts on the ultrasound image, and in the near future it will be possible to differentiate different pictures of different diseases (with alveolar interstitium involvement) on the basis of the iconographic representation of the vertical artifacts [17, 18]. The frequency characterization of vertical artifacts can be used as an indirect measure of the state of the lung, i.e., the lower the frequency at which B lines are visualized, the larger the channels formed between the alveoli and the more severe the lung condition [17, 18].

In the midst of the SARS-CoV-2 pandemic, a consensus of experts published a document suggesting the differentiation of vertical artifacts into B lines (BLA) or comet tail artifacts (CTA) [19]. The reverberation artefact (evaluated by low frequency transducer < 5 MHz without interfering presets) is called BLA if arising from a smooth pleural line (evaluated by high frequency transducer ≥ 10 MHz) [19]. The BLA arises from edema within the interstitium, is well defined with stable width, hyperechoic and extending indefinitely (the entire depth, at least 10 cm), erasing A-lines and moving with lung sliding [19]. The reverberation artefact is called CTA if arising from an irregular (or fragmented) pleural line (evaluated by high frequency transducer ≥ 10 MHz), changes in width (such as e a comet with narrow head and wide tail), is well defined, hyperechoic, and extending definitely (< 10 cm in depth) (evaluated by low frequency transducer < 5 MHz without interfering presets) [19].

Therefore, the vertical artifacts typically found in COVID-19 pneumonia seem to fall within the definition of
CTA, as well as those found in chronic interstitial pneumonia (Fig. 9).

Nowadays, those are only early and preliminar data. Certainly, COVID-19 pandemic is taking shape as a watershed in the history of lung ultrasound. Nowadays, the “simple” ultrasound finding of B lines seems to be limiting as compared to a wide range of differential diagnoses in the field of interstitial diseases (Fig. 10). In our opinion, in the near future we will have to make a differential diagnosis not by single signs detection, but by ultrasound patterns, with more ultrasound signs that combined with the clinical context can lead to an etiologically more specific diagnosis. Furthermore, the use of software and machines with diversified physical characteristics (use of different frequencies) will allow a further step towards a more accurate diagnosis.
Informed consent was obtained from all patients. Ethical approval by the institution's human research committee was not necessary.

Conflict of interest Authors declare no conflict of interest and no founding sources.

Declarations

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References

1. Volpicelli G, Gargani L, Perlini S, Spinelli S, Barbieri G, Lanotte A et al (2021) Lung ultrasound for the early diagnosis of COVID-19 pneumonia: an international multicenter study. Intensive Care Med 47(4):444–454. https://doi.org/10.1007/s00134-021-06373-3 (Epub 2021 Mar 20. PMID: 33743018; PMCID: PMC7980130)

2. Demi L, Mento F, Di Sabatino A, Fiengo A, Sabatini U, Macioce VN et al (2021) Lung ultrasound in COVID-19 and post-COVID-19 patients, an evidence-based approach. J Ultrasound Med. https://doi.org/10.1002/jum.15902 (Epub ahead of print. PMID: 34859905; PMCID: PMC9015439)

3. Spampinato MD, Sposato A, Migliano MT, Gordini G, Bua V, Sofia S (2021) Lung ultrasound severity index: development and usefulness in patients with suspected SARS-Cov-2 pneumonia—a prospective study. Ultrasound Med Biol 47(12):3333–3342. https://doi.org/10.1016/j.ultrasmedbio.2021.08.018 (Epub 2021 Aug 31. PMID: 34548188; PMCID: PMC8405447)

4. Sofia S, Boccatonda A, Montanari M, Spampinato M, D’ardes D, Cocco G et al (2020) Thoracic ultrasound and SARS-COVID-19: a pictorial essay. J Ultrasound 23(2):217–221. https://doi.org/10.1007/s00134-020-00458-7 (Epub 2020 Apr 16. PMID: 32297175; PMCID: PMC7159975)

5. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW et al (2012) International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med 38(4):577–591. https://doi.org/10.1007/s00134-012-2513-4 (Epub 2012 Mar 6 PMID: 22392031)

6. Lichtenstein D, Mezière G (1998) A lung ultrasound sign allowing bedside distinction between pulmonary edema and COPD: the comet-tail artifact. Intensive Care Med 24(12):1331–1334. https://doi.org/10.1007/s001340050771 (PMID: 9885889)

7. Sartini S, Frizzi J, Borselli M, Sarcoli E, Granai C, Galli V et al (2017) Which method is best for an early accurate diagnosis of acute heart failure? Comparison between lung ultrasound, chest X-ray and NT pro-BNP performance: a prospective study. Intern Emerg Med 12(6):861–869. https://doi.org/10.1007/s11739-016-1498-3 (Epub 2016 Jul 11 PMID: 27401330)

8. Cogliati C, Casazza G, Ceriani E, Torzillo D, Furlotti S, Bossi I et al (2016) Lung ultrasound and short-term prognosis in heart failure patients. Int J Cardiol 1(218):104–108. https://doi.org/10.1016/j.ijcard.2016.05.010 (Epub 2016 May 13 PMID: 27232920)

9. Aras MA, Teerlink JR (2016) Lung ultrasound: a “B-line” to the prediction of decompensated heart failure. Eur Heart J 37(15):1252–1254. https://doi.org/10.1093/eurheartj/ehw094 (PMID: 27080198)

10. Patel CJ, Bhatt HB, Parikh SN, Jhaveri BN, Puranik JH (2018) Bedside lung ultrasound in emergency protocol as a diagnostic tool in patients of acute respiratory distress presenting to emergency department. J Emerg Trauma Shock 11(2):125–129. https://doi.org/10.1017/jets.2017.251 (PMID: 29376643; PMCID: PMC5994850)

11. Sekiguchi H, Schenck LA, Horie R, Suzuki J, Lee EH, McMenemy BP et al (2015) Critical care ultrasonography differentiates ARDS, pulmonary edema, and other causes in the early course of acute hypoxic respiratory failure. Chest 148(4):912–918. https://doi.org/10.1378/chest.15-0341 (PMID: 25966139)

12. Manolescu D, Oancea C, Timar B, Traila D, Malita D, Birsanetea F et al (2020) Ultrasound mapping of lung changes in idiopathic pulmonary fibrosis. Clin Respir J 14:54–63. https://doi.org/10.1111/crj.13101

13. Reissig A, Copetti R (2014) Lung ultrasound in community-acquired pneumonia and in interstitial lung diseases. Respiration 87(3):179–189. https://doi.org/10.1159/000357449 (Epub 2014 Jan 28 PMID: 24481027)

14. Doveri M, Frassi F, Consensi A, Vesprini E, Gargani L, Tafuri M et al (2008) Lung ultrasound comets: new echographic sign of lung interstitial fibrosis in systemic sclerosis. Reumatismo 60:180–184. https://doi.org/10.4081/reumatismo.2008.180

15. Spersandeo M, De Cata A, Molinaro F, Trovato FM, Catalano D, Simeone A et al (2015) Ultrasound signs of pulmonary fibrosis in systemic sclerosis as timely indicators for chest computed tomography. Scand J Rheumatol 44:389–398. https://doi.org/10.3109/03009742.2015.1011228
16. Barskova T, Gargani L, Guiducci S, Randone SB, Bruni C, Carnesecchi G et al (2013) Lung ultrasound for the screening of interstitial lung disease in very early systemic sclerosis. Ann Rheum Dis 72:390–395. https://doi.org/10.1136/annrheumdis-2011-201072

17. Mento F, Demi L (2020) On the influence of imaging parameters on lung ultrasound B-line artifacts, in vitro study. J Acoust Soc Am 148(2):975. https://doi.org/10.1121/10.0001797 (PMID: 32873037)

18. Peschiera E, Mento F, Demi L (2021) Numerical study on lung ultrasound B-line formation as a function of imaging frequency and alveolar geometries. J Acoust Soc Am 149(4):2304. https://doi.org/10.1121/10.0003930 (PMID: 33940883)

19. Mathis G, Horn R, Morf S, Prosch H, Rovida S, Soldati G et al (2021) WFUMB position paper on reverberation artefacts in lung ultrasound: B-lines or comet-tails? Med Ultrasound 23(1):70–73. https://doi.org/10.11152/mu-2944 (PMID: 33621275)

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