AJRCCM Articles in Press. Published on 20-March-2018 as 10.1164/rccm.201802-0227LE

Training for Lung Ultrasound Score Measurement in Critically Ill Patients

Jean-Jacques Rouby, M.D., Ph.D.
Charlotte Arbelot, M.D.,
Multidisciplinary Intensive Care Unit, Department of Anesthesiology and Critical Care Medicine, La Pitié-Salpêtrière hospital, Assistance Publique Hôpitaux de Paris, University Pierre and Marie Curie Paris 6, France

Yuzhi Gao, M.D.
Mao Zhang, M.D., Ph.D.
Emergency Intensive Care Unit, Department of Emergency Medicine, 2nd Affiliated Hospital, Zhejiang University School of Medicine, Institute of Emergency Medicine, Zhejiang University, Hangzhou, China

Jie Lv, M.D.,
Youzhong An, M.D., Ph.D.
Multidisciplinary Intensive Care Unit, Department of Critical Care Medicine, Peking University People's Hospital, Peking University Health Center Science, Beijing, China

Chunyao Wang, MD,
Du Bin, M.D, Ph.D.
Medical Intensive Care Unit, Peking Union Medical College Hospital, Beijing, China.

Carmen Silvia Valente Barbas, M.D., Ph.D.
Multidisciplinary Intensive Care Unit, Hospital Albert Einstein, São Paulo, Brazil.

Felippe Leopoldo Dexheimer Neto, M.D., Ph.D.
Intensive Care Unit, Ernesto Dornelles Hospital, Hospital Moinhos de Vento and Programa de Pós Graduação em Ciências Pneumológicas, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Fabiola Prior Caltabeloti, M.D., Ph.D.
Surgical and Trauma Intensive Care Unit, Hospital Das Clinicas, University of São Paulo, São Paulo, Brazil

Emidio Lima, M.D., Ph.D.
Multidisciplinary Intensive Care Unit, Hospital da Bahia, Salvador and Santa Helena Hospital, Camaçari, Bahia, Brazil.

Andres Cebey, M.D.
Intensive Care Unit, Hospital de Clínicas Dr Manuel Qintela, Faculdade de Medicina, Universidad de la Republica, Montevideo, Uruguay

Sébastien Perbet, M.D.
Jean-Michel Constantin, M.D., Ph.D
Department of Peri-Operative Medicine, Centre Hospitalo-Universitaire Clermont-Ferrand, INSERM, CNRS, Université Clermont Auvergne, Clermont-Ferrand, France.

For the APECHO study group*

The APECHO study group members, listed according to their Institution, include: Charlotte Arbelot, Jean-Jacques Rouby, Hélène Brisson, Romain Deransy, Corinne Vezinet, Pierre Garçon, Nabil El Hadj Kacem, Denis Lemesle, Antoine Monsel, Qin Lu, Olivier Langeron, (Multidisciplinary Intensive Care Unit, Department of Anaesthesiology and Critical Care Medicine, La Pitié-Salpêtrière hospital, Assistance Publique Hôpitaux de Paris, University Pierre and Marie Curie Paris 6, France.); Frédérick Gay (Department of Parasitology-Mycology, La Pitié-Salpêtrière hospital, Assistance Publique Hôpitaux de Paris, University Pierre and Marie Curie Paris 6, France); Bruno Lucena, Luiz Malbouisson, Maria José Carvalho Carmona (Surgical and Trauma Intensive Care Unit, Hospital Das Clinicas, University of São Paulo, São Paulo, Brazil); Julio Neves (Multidisciplinary Intensive Care Unit, Hospital da Bahia); Paulo de Tarso Roth Dalcin (Intensive Care Unit, Ernesto Dornelles Hospital, Hospital Moinhos de Vento and Programa de Pós Graduação em Ciências Pneumológicas, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil.); Guilherme de Paula Pinto Schettino (Multidisciplinary Intensive Care Unit, Hospital Albert Einstein, São Paulo, Brazil.); Alberto Biestro (Intensive Care Unit, Hospital de Clínicas Dr Manuel Qintela, Faculdade de Medicina, Universidad de la Republica, Montevideo, Uruguay) ; Davi Cristovao, Jorge Salluh (Multidisciplinary Intensive Care Unit, Hospital Copa D'Or, Rio de Janeiro, Brazil.)

Corresponding Author for requests for reprints and correspondence: Pr Jean-Jacques Rouby, Multidisciplinary Intensive Care Unit, La Pitié-Salpêtrière Hospital, University Pierre and Marie Curie (UPMC) Paris 6, France jjrouby@invivo.edu

Word count: 868

Keywords: Lung Ultrasound Score, training, critically ill patients, acute respiratory failure

AJRCCM Articles in Press. Published on 20-March-2018 as 10.1164/rccm.201802-0227LE

*To the Editor***,**

Bedside Lung ultrasound is widely used in critically-ill and emergency patients (1). Its role in pulmonary imaging has been recently reviewed (2). A Lung Ultrasound Score (LUS), based on the examination of 12 regions of interest has been proposed to assess lung aeration changes following various therapeutic interventions in mechanically ventilated patients (3,4). As shown in figure 1, the LUS is based on regional aeration of each examined region which is graded between 0 and 3, depending on the degree of aeration loss. The LUS score is a semi-quantitative assessment of pulmonary aeration loss and can vary between 0 and 36.

In anesthetized patients scheduled for abdominal surgery, lung ultrasound detects intraoperative atelectasis and LUS correlates with perioperative oxygenation impairment (5). In patients with acute respiratory distress syndrome, LUS is correlated with severity and predicts mortality (6). It provides a comprehensive monitoring of regional lung aeration changes resulting from prone positioning (7), fluid loading (4), positive end-expiratory pressure (8) and drainage of large pleural effusion (9). In ventilated critically-ill patients with ventilator-associated pneumonia, the rapid decrease in LUS attests successful antimicrobial therapy-induced lung re-aeration whereas an increase in LUS attests antibiotic failure (10). During weaning from mechanical ventilation, a LUS > 13 measured at the end of a clinically successful spontaneous breathing trial is predictive of extubation failure (3).

Despite the increased interest for LUS, training methods to acquire appropriate skills for LUS measurement are variable between centers and not codified. Based on the clinical experience accumulated over 10 years of resident training including the acquisition of skills in lung ultrasound, we hypothesized that 25 LUS determinations supervised by experts would be enough for trainees without expertise in lung ultrasound to appropriately assess LUS. A multicentre, prospective and educational study whose aim was the acquisition of basic skills for bedside lung ultrasound, was conducted in 10 Intensive Care Units in Brazil, China, France and Uruguay. The training course started with a 2-hour video lecture. First, ultrasound patterns characterizing normal aeration, moderate aeration loss (interstitial syndrome, localized alveolar edema and subpleural consolidations), severe aeration loss (diffuse alveolar edema), and complete aeration loss (consolidation) were described. Second, the method for assessing Lung Ultrasound Score was carefully described. One of the objectives of the training program was to reach an agreement in LUS between trainees and experts. Each trainee had to perform 25 bedside determinations of LUS supervised by an expert. Experts participating into the training protocol were staff members in critical care or emergency medicine with at least a 2-year daily lung ultrasound practice. Every five supervised lung ultrasound examinations, the trainee and the expert assessed the LUS in the same patient separately. Concordance was considered as clinically acceptable when LUS assessment did not differ by more than 2 between trainees and experts. Six hundred and ten comparative LUS measurements were performed by 100 trainees and 18 experts in 233 mechanically ventilated and 137 spontaneously breathing critically ill patients. As shown in figure 2, concordance between trainees and experts was obtained on the 6th evaluation.

Median duration of training (interquartile 25 and 75) was 51 (23, 69) days. At the end of the training, the median time required to measure LUS was 8 (3, 14) minutes for experts and 10 (4,17) minutes for trainees.

This study shows that residents and seniors without expertise in lung ultrasound can acquire the skills required to measure LUS after 25 supervised measurements. The training should include appropriate recognition of normal aeration, interstitial syndrome, alveolar edema and lung consolidation, all ultrasound patterns necessary to calculate LUS. Two issues which could interact with accurate determination of LUS deserve specific comments. Alveolar edema, characterized by the presence of coalescent B lines, can remain localized, as

AJRCCM Articles in Press. Published on 20-March-2018 as 10.1164/rccm.201802-0227LE

in acute respiratory distress syndrome, or be diffuse, as in cardiogenic pulmonary edema. When an examined region is characterized by "focal" alveolar edema, corresponding to "ground glass area" on lung computed tomography, the loss of lung aeration is moderate, and the region should be graded 1. When the examined region is characterized by diffuse alveolar edema, the loss of lung aeration is severe, and the region should be graded 2. As recently recommended (11), when coalescent B lines occupy less than 50% of the intercostal space in transversal plane, graduation should be 1; when coalescent B lines occupy more than 50% of the intercostal space, graduation should be 2. Systematic gradation 2 in presence of coalescent B lines without considering their extension, could lead to overestimation of LUS and aeration loss. The same reasoning also applies for subpleural consolidations that characterize ventilator-associated pneumonia (12). These small subpleural consolidations, representative of foci of bronchopneumonia, have dimensions varying between 5 and 15 mm, are limited by spaced or coalescent B lines, and are associated with moderate loss of lung aeration (13). For this reason, regions characterized by subpleural consolidations should be graded 1 and not 3.

In conclusion, the measurement of LUS as a monitoring tool of lung aeration in critically ill patients, requires a short and easy-to-implement training, based on 25 ultrasound examinations supervised by a physician with expertise in bedside lung ultrasound.

Acknowledgment

We would like to thank Professor Pascaline Faure, Ph.D., Director of the Medical English Department, Pierre and Marie Curie School of Medicine (UPMC), Paris 6, Sorbonne University, Paris, France for reviewing the English of the article.

AJRCCM Articles in Press. Published on 20-March-2018 as 10.1164/rccm.201802-0227LE

LEGENDS FOR FIGURES

Figure 1. Lung Ultrasound Score assessment. Six lung regions of interest, delineated by parasternal line (PSL), anterior axillary line (AAL), posterior axillary line (PAL) and paravertebral line (PVL) are examined on each side. Each lung region is carefully examined in longitudinal plane and, each intercostal space present in the region, is examined in transversal plane. The worst ultrasound pattern characterizes the region (regional LUS) using the following grading: 0= normal aeration; 1= moderate loss of aeration: interstitial syndrome, defined by multiple spaced B lines, or localized pulmonary edema, defined by coalescent B lines in less than 50% of the intercostal space examined in transversal plane, or subpleural consolidations ; 2 = severe loss of aeration: alveolar edema defined by diffused coalescent B lines occupying the whole intercostal space; 3 = complete loss of lung aeration: lung consolidation defined as a tissue pattern with or without air bronchogram. Lung Ultrasound Score is calculated as the sum of the 12 regional scores.

Figure 2: Difference between Lung Ultrasound Score (LUS) measured by trainees and experts over six successive evaluations. The first evaluation was performed two hours after a lecture describing the method for measuring LUS. Further evaluations were separated by five ultrasound examinations performed by the trainee and supervised by the referent. The pink zone indicates the limit of agrement between trainees and experts.

AJRCCM Articles in Press. Published on 20-March-2018 as 10.1164/rccm.201802-0227LE

References

1. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, Melniker L,Gargani L, Noble VE, Via G, Dean A, Tsung JW, et al. International Liaison Committee on Lung Ultrasound (ILC-LUS) for International Consensus Conference on Lung Ultrasound (ICC-LUS). International evidence-based recommendations for point-of-care lung ultrasound. *Int Care Med* 2012; 38: 577-591.

2. Bellani G, Rouby JJ, Constantin JM, Pesenti A. Looking closer at acute respiratory distress syndrome : the role of advanced imaging technique (2017) *Cur Op Crit Care* 2017; 23:30-37.

3. Soummer A, Perbet S, Brisson H, Arbelot C, Constantin JM, Lu Q, Rouby JJ and the Lung Ultrasound Study Group. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. *Crit Care Med* 2012; 40:2064-2072.

4. Caltabeloti F, Monsel A, Arbelot C, Brisson H, Lu Q, Gu WJ, Zhou GJ, Auler Jr JOC and Rouby JJ. Early fluid loading in acute respiratory distress syndrome with septic shock deteriorates lung aeration without impairing arterial oxygenation: a lung ultrasound observational study. *Crit Care* 2014; 18(3): R91

5. Monastesse A, Girard F, Massicotte N, Chartrand-Lefebvre C, Girard M. *Anesth Analg* 2017; 124:494-504.

6. Li L, Yang Q, Li L, Guan J, Liu Z, Han J, Chao Y, Wang Z, Yu X. The value of lung ultrasound score on evaluating clinical severity and prognosis in patients with acute respiratory distress syndrome. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xu* 2015; 27:579-584.

7. Haddam M, Zieleskiewicz L, Perbet S, Baldovini A, Guervilly C, Arbelot C, Noel A, Vigne C, Hammad E, Antonini F, et al. CAR'Echo Collaborative Network; AzuRea Collaborative Network. Lung ultrasonography for assessment of oxygenation response to prone position ventilation in ARDS. *Intensive Care Med* 2016; 42:1546-1556.

8. Bouhemad B, Brisson H, Le Guen M, Arbelot C, Lu Q, Rouby JJ. Bedside Ultrasound Assessment of Positive-End Expiratory Pressure-Lung Recruitment. *Am J Respir Crit Care Med* 2011; 183: 1-7

9. Chinardet B, Brisson H, Arbelot C, Langeron O, Rouby JJ, Lu Q. Ultrasound assessment of lung consolidation and reaeration after pleural effusion drainage in patients with Acute Respiratory Distress Syndrome: a pilot study. *Acta Anaesth Belg* 2016; 67:29-35.

10. Bouhemad B, Liu ZH, Arbelot C, Zhang M, Ferarri F, Le-Guen M, Girard M, Lu Q, Rouby JJ. Ultrasound assessment of antibiotic-induced pulmonary reaeration in ventilator-

associated pneumonia. *Critical Care Medicine* 2010; 38: 84-92. Transthoracic lung ultrasound in emergency and critically ill patients: training and learning curve.

11. Mongodi S, Bouhemad B, Orlando A, Stella A, Tavazzi G, Via G, Iotti GA, Braschi A, Mojoli F. Modified Lung Ultrasound Score for Assessing and Monitoring Pulmonary Aeration. *Ultraschall Med* 2017; 38: 530-537.

12. Mongodi S, Via G, Girard M, Rouquette I, Misset B, Braschi A, Mojoli F, Bouhemad B. Lung Ultrasound for Early Diagnosis of Ventilator-Associated Pneumonia. *Chest* 2016 .149: 969-980.

13. Bouhemad B, Mongodi S, Via G, Rouquette I. Ultrasound for "lung monitoring" of ventilated patients. *Anesthesiology* 2015; 122: 437-447.

AJRCCM Articles in Press. Published on 20-March-2018 as 10.1164/rccm.201802-0227LE

Each intercostal space present in each lung region is explored and the most severe ultrasound pattern characterizes the examined region (***lung regional score: 0, 1, 2 or 3***)

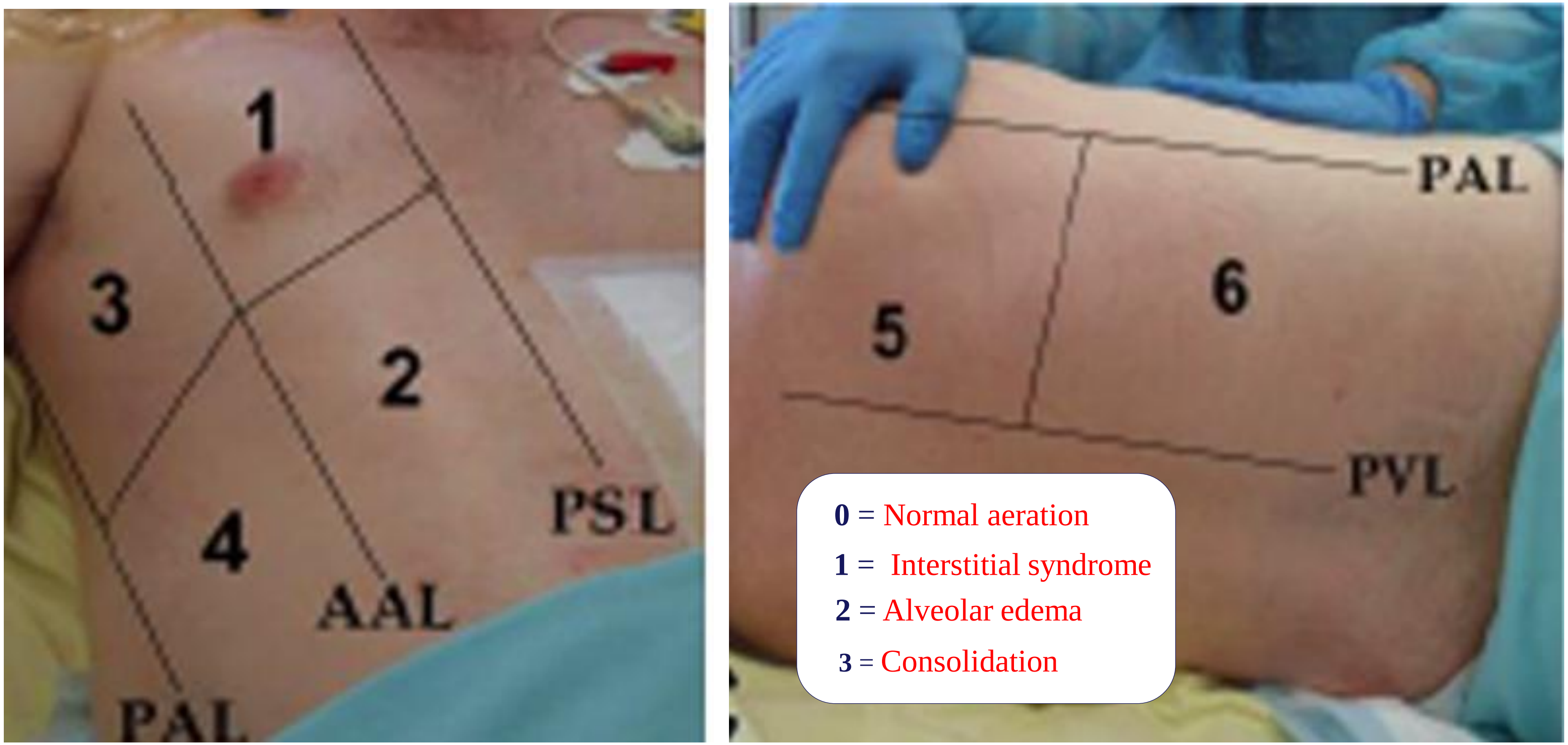

Figure 1

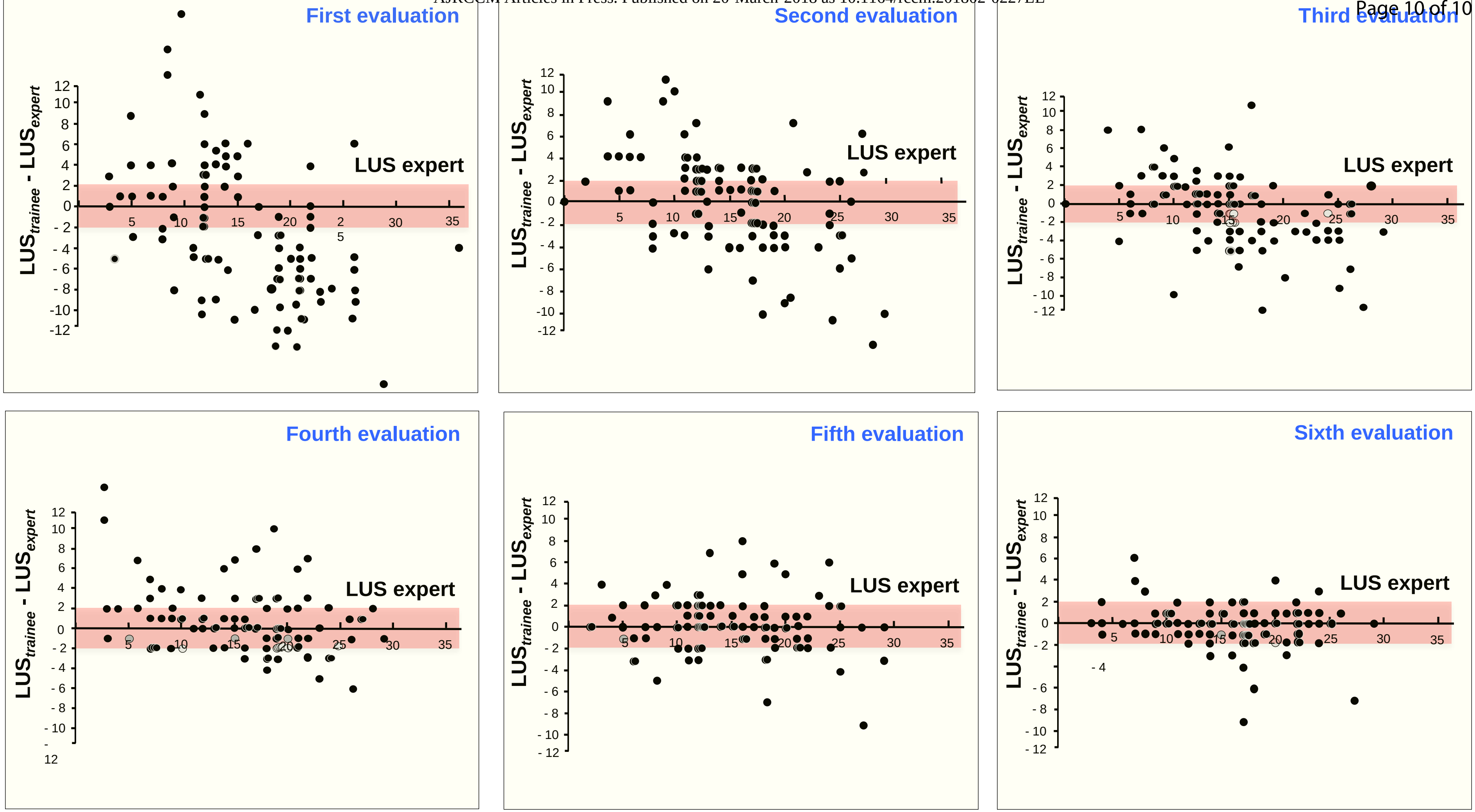
First evaluation
Second evaluation
Third evaluation
Fourth evaluation
Fifth evaluation
Sixth evaluation
LUS expert
$LUS_{trainee}$ - LUS_{expert}

Figure 2