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Measurement of crackles during sleep may have a role to play in titration of positive airway pressure (PAP) modalities in heart failure

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1. Introduction to the case

Interstitial lung edema is one potential mechanism of central sleep apnea (CSA) in heart failure. The control of edema by continuous positive airway pressure (CPAP) may explain why CSA improves in some patients [1]. Crackles are physical signs of lung congestion and severity of heart failure. Our aim was to determine the impact of positive pressure therapies on sleep-disordered breathing and crackles in a patient with CSA and heart failure.

We studied one unmedicated 56-year-old male (BMI 23 kg/m^2) with CSA and heart failure (LVEF 47%) 10 years post-infarct. Crackles were absent upright, developing when horizontal. Multiple home-based sleep investigations were performed using the Sonomat, a mat overlay containing non-contact electronic stethoscopes [2]. Recordings of crackles, replayed for auscultation, were scored using published guidelines [3]. Investigations included 11 diagnostic (Dx), 13 CPAP, 7 adaptive servo-ventilation (ASV) studies, and 3 post-treatment studies (Dx2) of this patient. We calculated the central apnea/hypopnea index (CAHI), latency to first three consecutive crackling breaths (min), and crackle duration (% analysis time). Median (interquartile range) values are reported.

2. Image analysis

Fig. 1 shows breathing movement traces and breath sound/auscultation traces during diagnostic, CPAP and ASV studies. Crackles are large amplitude deflections on the breath sound trace. In this image, central apneas and crackles are both present on diagnostic (Fig. 1A). Crackles are eliminated on CPAP but central apneas are present (Fig. 1B). Using ASV crackles remain but without central apneas (Fig. 1C).

Fig. 2 shows CAHI and crackle duration for all studies. Severe CSA on Dx (CAHI = 64 [60, 66]/hr), improved on CPAP (CAHI = 31 [22, 42.5]/hr; $p < 0.01$) and ASV (CAHI = 3.0 [3.0, 5.0]/hr; $p < 0.01$). Crackle duration decreased from baseline of 41 (31, 48)% to 14 (7, 22)% ($p < 0.01$) using CPAP and 15 (10, 16)% ($p < 0.05$) with ASV. CPAP pressures were titrated over multiple nights (7 to max 12cmH_20 for final two nights) with crackles reducing as pressure increased; central apneas decreased but were not eliminated. The ASV was set to automatic mode with minimum expiratory positive airway pressure (EPAP) pressure 8cmH2O; this effectively eliminated CSA and reduced crackle duration.

Crackle latency (not shown) at baseline was 13 (6, 37) min, which increased on CPAP to 55 (29, 110) min; $p < 0.05$. ASV had no significant effect on crackle latency (15 [13, 54] min).

3. Discussion

CPAP reduced central apneas and was associated with decreased crackle duration and increased crackle latency. In contrast, ASV eliminated central apneas and reduced crackle duration, but crackle

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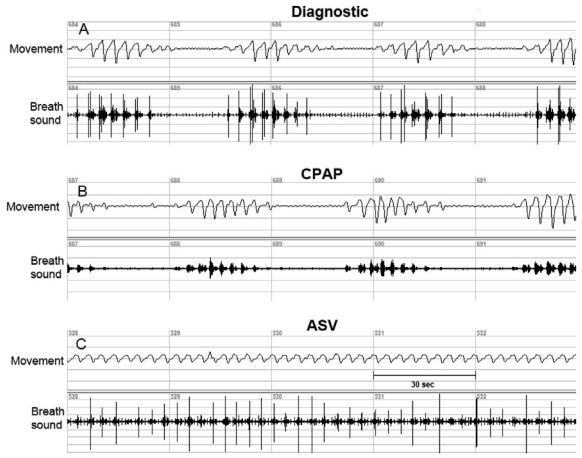

Fig. 1. Sonomat recordings (150 s); (A) Diagnostic, (B) CPAP, (C) ASV.

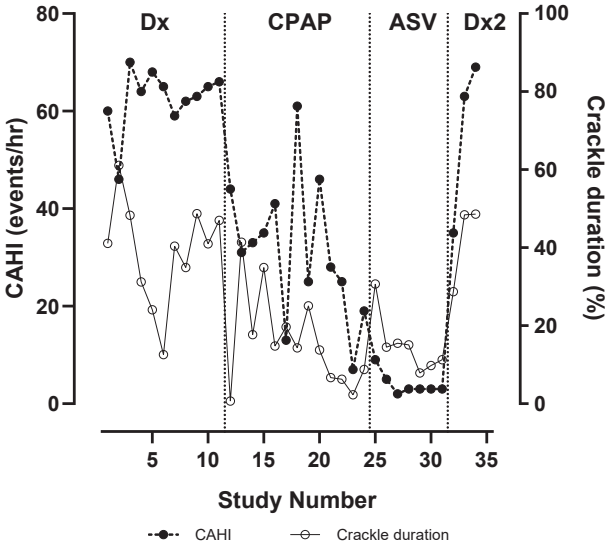

Fig. 2. CAHI (events/hr) and crackle duration (%) for each Sonomat recording for this 56-year-old male including diagnostic (Dx), CPAP, ASV and follow up diagnostic studies (Dx2).

latency was unchanged. These preliminary measurements demonstrate that recording crackles may be useful in unravelling the relationships between lung congestion and CSA. Unchanged crackle latency on ASV may be related to a lower EPAP pressure and titration of EPAP, targeting crackle elimination in addition to upper airway obstruction, may improve the clinical effects of ASV in treating CSA. This warrants further investigation.

The simplicity of the Sonomat enables long-term measurements of breathing, including lung auscultation, providing a tool for N of 1 studies to track changes and explore the effectiveness of potential therapies.

CRediT authorship contribution statement

Maree A. Milross: Conceptualization, Methodology, Validation, Formal analysis, Writing - original draft, Writing - review & editing. **Mark B. Norman:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - review & editing, Visualization, Project administration. **Michael Wilson:** Methodology, Investigation, Writing - review & editing, Project administration. **Gary Baker:** Writing - review & editing. **Ian Wilcox:** Conceptualization, Methodology, Writing - review & editing. **Colin E. Sullivan:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing - review & editing, Supervision, Project administration.

Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleepx.2021.100034.

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