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Pre-endoscopic bowel sound analysis using a modified digital stethoscope: a monocentric pilot study correlating acoustic, clinical, and endoscopic findings

K. Bouslama

kais.bouslama@gmail.com

University of Tunis Manar, Mongi Slim Hospital

N. G. Abassi

École Polytechnique Fédérale de Lausanne

A. Nakhli

University of Tunis Manar, Mongi Slim Hospital

D. Pohl

University Hospital Zurich

D. Gillet

École Polytechnique Fédérale de Lausanne

A. Jerbi

University of Tunis Manar, Mongi Slim Hospital

Z. Benzarti

University of Tunis Manar, Mongi Slim Hospital

N. Hemdani

University of Tunis Manar, Mongi Slim Hospital

B. Bouchabou

University of Tunis Manar, Mongi Slim Hospital

R. Ennaifer

University of Tunis Manar, Mongi Slim Hospital

Article

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Additional Declarations: Competing interest reported. This study was conducted in collaboration with Digehealth, a Swiss startup developing a portable device for continuous intestinal sound monitoring. Digehealth provided the modified digital stethoscope, technical support and access to data engineers who contributed to acoustic feature extraction and model implementation. A confidentiality agreement was signed between the academic team and Digehealth. The authors declare no other conflicts of interest.

Abstract

Background

Bowel sounds reflect gastrointestinal motility but are rarely used in clinical decision-making, largely because conventional auscultation is brief, subjective, and poorly standardized. Advances in digital stethoscopes and acoustic signal processing create opportunities to transform bowel sounds into quantitative biomarkers.

Aims

To explore whether acoustic features extracted from pre-endoscopic bowel sound recordings are associated with clinical characteristics and endoscopic findings in patients undergoing colonoscopy.

Methods

We conducted a monocentric, observational, cross-sectional study in the gastroenterology department of Mongi Slim Hospital (Tunisia) between March and June 2023. Consecutive adult patients scheduled for colonoscopy after a standardized low-residue diet and bowel preparation underwent a structured interview, physical examination and a five-minute abdominal sound recording within one hour before the procedure. Recordings were obtained over the right iliac fossa using a modified Littmann CORE digital stethoscope equipped with a piezoelectric sensor (1) connected directly to a smartphone. Sounds were manually labelled as bowel sounds, environmental noise or artefacts and subclassified into single bursts [sb], multiple bursts [mb] and harmonic sounds [h]. Acoustic features were extracted per labelled event and aggregated per patient (method A) and per sound subtype (method B), then entered multivariable logistic regression models to assess associations with selected clinical and endoscopic outcomes (significance threshold: $p < 0.05$).

Results

Ninety-five patients were included (mean age 56 ± 15 years; 48 men, 47 women). Colonoscopy was performed in 83 patients (87%), and at least one endoscopic abnormality was identified in 47 (57%). A total of 33,837 bowel sounds were labelled across all recordings. Sex, BMI, and difficulty passing gas were significantly associated with amplitude-related acoustic parameters (RMS and envelope). The presence of endoscopic abnormalities, particularly colonic polyps, was also significantly associated with these parameters and additionally with zero-crossing rate. Bowel preparation quality and time since last liquid intake showed consistent associations with spectral contrast, number of labels and zero-crossing.

Conclusions

In this pilot study, standardized pre-colonoscopy bowel sound recordings analysed using multivariable logistic regression yielded acoustic features nominally associated with clinical characteristics and endoscopic findings. These results are consistent with the feasibility of intestinal sound analysis as a non-invasive biomarker, but require confirmation in larger, multicentric and externally validated cohorts before clinical integration.

Introduction

The diagnostic work-up of colonic disease increasingly relies on costly and invasive procedures such as colonoscopy, which can be burdensome and anxiety-provoking for patients. There is a persistent need for complementary tools that are non-invasive, inexpensive and capable of providing objective information on intestinal function before, during or after endoscopic assessment.

Borborygmi are the audible manifestation of intestinal peristalsis and, in principle, could serve as an accessible marker of gastrointestinal motility. Abdominal auscultation is simple and widely available, yet it remains qualitative, operator-dependent and limited to very short time windows, which has hindered its integration into modern decision-making algorithms. Earlier attempts to record bowel sounds with conventional audio devices allowed prolonged monitoring but were hampered by poor noise filtering and the impracticality of manual analysis of long recordings (2) (3) (4).

Recent progress in digital health has revived interest in intestinal acoustics. Digehealth, a Swiss startup with which the study team collaborated, has initiated the development of a portable device dedicated to continuous monitoring of bowel sounds, combining adapted hardware, optimized audio acquisition and advanced signal processing. Within this broader program, our work represented an initial clinical step, aiming to determine whether pre-endoscopic bowel sound recordings, acquired under standardized conditions, could be linked to patients' clinical profiles and endoscopic findings. The relationship between this academic study and Digehealth is disclosed in the Conflicts of Interest section.

The present study therefore sought to correlate acoustic features of intestinal sounds with clinical and endoscopic variables in patients undergoing colonoscopy in a tertiary gastroenterology department. By leveraging a modified digital stethoscope, manual sound labelling and multivariable logistic regression, we aimed to explore the feasibility and potential diagnostic relevance of bowel sound analysis as a non-invasive biomarker in everyday practice.

Methods

Study design and setting

We conducted a monocentric, observational, cross-sectional study in the gastroenterology department of Mongi Slim Hospital in Tunisia over a predefined inclusion period between March and June 2023. All procedures were embedded in the routine pre-colonoscopy pathway of the unit, without modification of the indication or conduct of the endoscopic examination.

Ethical considerations

Ethical approval

was obtained from the Institutional Ethics Committee of Mongi Slim Hospital prior to study initiation. All methods were performed in accordance with the relevant guidelines and regulations, and the study was conducted in accordance with the Declaration of Helsinki. Each patient provided oral informed consent after explanation of the study objectives. All data were pseudonymized, with each patient assigned an anonymous code to link clinical, endoscopic and acoustic data. A confidentiality agreement was signed between the academic team and Digehealth.

Study population

Eligible participants were adult patients scheduled to undergo colonoscopy in the gastroenterology department, irrespective of indication. All patients followed a low-residue diet for at least three days and ingested a bowel preparation solution the day before the procedure, according to local protocols. Because food intake is a major determinant of bowel sounds, harmonizing dietary conditions and preparation was considered crucial to reduce measurement bias and obtain a more homogeneous sample.

Non-inclusion criteria were lack of consent and the presence of an intestinal stoma. Patients who did not adhere to the recommended low-residue diet and/or did not take the prescribed bowel preparation the day before colonoscopy were excluded.

Clinical data collection

Within the hour preceding colonoscopy, the investigator conducted a structured interview and physical examination. After informed consent, clinical data were collected including: demographic information; relevant medical history (chronic inflammatory bowel disease, thyroid dysfunction, diabetes, arterial hypertension, prior colorectal or intestinal surgery); bowel habits over the preceding month; Bristol stool scale category; abdominal bloating; difficulty passing gas; abdominal pain; visible gastrointestinal bleeding; and perceived stress assessed using the Perceived Stress Scale. Physical examination included measurement of weight, height, body mass index (BMI), waist circumference and abdominal percussion (tympanic vs dull). Preparation compliance, regimen type and time since last liquid intake were also documented.

Bowel sound recording

Recordings were performed by a single investigator in a standardized setting. The patient lay supine, breathed calmly, and the stethoscope chest piece was applied directly to the skin over the right iliac

fossa for five minutes. A Littmann CORE digital stethoscope was modified by mounting a piezoelectric sensor (1) connected directly to a smartphone via cable, as shown in Fig. 1, bypassing the Bluetooth Low Energy interface to enhance frequency range, improve signal specificity and avoid compression.

Endoscopic data

Endoscopic data were collected prospectively from colonoscopy reports, including indication; maximal extent reached; bowel preparation quality (Boston Bowel Preparation Scale, or qualitatively graded as good, fair or poor for operated colons); presence of abnormalities; and type, location and presumed diagnosis of lesions.

Signal processing and labelling

Audio files were imported into Audacity (v3.2.5) and visualized as spectrograms. Each recording was inspected segment by segment, with amplification applied to facilitate detection of low-amplitude events as shown in Fig. 2. Sounds were classified into environmental noise, stethoscope artefacts and intestinal sounds, the latter subclassified into single bursts [sb], multiple bursts [mb] (separated by intervals < 60 ms) and harmonic sounds [h], following a previously published scheme (1) (5) as shown in Fig. 3.

Labelling was performed in two passes by the single investigator: a first pass using direct manual labelling or semi-automatic labelling by a model developed by Digehealth; and a second pass in which the investigator reviewed and corrected all labels. Labelling was performed by a single observer; intra- and inter-observer reproducibility were not formally assessed in this study, which constitutes a recognized limitation.

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Figure 3

The different types of recorded sounds – single burst [sb]; multiple burst [mb] ; harmonic sound [h] ; surrounding noise artifact[n] ; stethoscope or digital artifact [z].

Acoustic feature extraction

Feature extraction was conducted in collaboration with Digehealth data engineers using Python. For each labelled intestinal sound, the following features were computed: duration, Mel-frequency cepstral coefficients (MFCCs) (6), root mean square amplitude (RMS) (7), spectral centroid (8), spectral bandwidth (9), spectral roll-off (10), spectral contrast (11), zero-crossing rate (8), chroma (8) and envelope (12). Recording-level summaries included total label count, bowel sounds per minute and the label-to-recording ratio (RLE).

Statistical analysis

Two aggregation strategies were applied: method A computed mean values of each acoustic parameter across all bowel sounds per patient; method B computed means separately for each sound subtype (single burst, multiple bursts, harmonic). These aggregated values were entered as predictors into separate multivariable logistic regression models for selected binary clinical and endoscopic outcomes. Regression coefficients, p-values and 95% confidence intervals (CIs) were reported. A p-value < 0.05 was the threshold for nominal statistical significance.

Given the exploratory nature of this study and the large number of acoustic features tested simultaneously, no correction for multiple comparisons was applied; all reported associations should therefore be regarded as hypothesis-generating and subject to type I error inflation.

Results

1. **1. Descriptive findings**
2. **1.1 Epidemiological and clinical characteristics**

Ninety-five patients were enrolled. Table 1 summarizes the main characteristics of the study population. The cohort comprised 48 men (51%) and 47 women (49%), with a mean age of 56 ± 15 years (range 22–82). Seventy-three patients (77%) had at least one medical comorbidity, most frequently arterial hypertension (23 patients, 24%). Ten patients were followed for chronic inflammatory bowel disease (8 Crohn's disease, 2 ulcerative colitis) and six had a history of colorectal cancer, of whom only one had active disease at inclusion.

Functional symptoms were frequent: bloating in 45 patients (47%), and transit disorders in 40 (42%), predominantly constipation (31 patients, 77% of those with altered transit). Seventeen patients (18%) reported frequent or very frequent difficulty passing gas.

BMI was assessed in 65 patients: one patient was underweight (< 18.5 kg/m²), 29 (45%) had normal weight (18.5–24.9 kg/m²), 18 (28%) were overweight (25.0-29.9 kg/m²) and 17 (26%) were obese (≥ 30.0 kg/m²). Waist circumference was measured in 93 patients: 28 (30%) had normal values and 65 (70%) had elevated or very elevated waist circumference. Abdominal percussion was performed in 88 patients: 54 (61%) were tympanic and 34 (39%) dull.

Table 1
Baseline characteristics of the study population (n = 95)

Characteristic	Value
Age, mean ± SD (years) [range]	56 ± 15 [22–82]
Sex, n (%)	
Male	48 (51%)
Female	47 (49%)
Medical comorbidities ≥ 1, n (%)	73 (77%)
Arterial hypertension	23 (24%)
Chronic inflammatory bowel disease	10 (11%)
History of colorectal cancer	6 (6%)
BMI categories (n = 65), n (%)	
Underweight (< 18.5 kg/m²)	1 (1.5%)
Normal weight (18.5–24.9 kg/m²)	29 (45%)
Overweight (25.0-29.9 kg/m²)	18 (28%)
Obese (≥ 30.0 kg/m²)	17 (26%)
Waist circumference (n = 93), n (%)	
Normal	28 (30%)
Elevated or very elevated	65 (70%)
Functional symptoms, n (%)	
Bloating	45 (47%)
Transit disorders	40 (42%)
Difficulty passing gas (frequent/very frequent)	17 (18%)
Abdominal percussion (n = 88), n (%)	
Tympanic	54 (61%)
Dull	34 (39%)
Bowel preparation regimen, n (%)	
Sodium picosulfate	56 (59%)
Split polyethylene glycol	35 (37%)
Continuous polyethylene glycol	4 (4%)

Characteristic	Value
Time since last liquid intake, mean (hours) [range]	5.06 [1–12]; median 4.5 h
Preparation completed 3–6 h before recording	64 (67%)
Colonoscopy performed, n (%)	83 (87%)
Complete (to caecal pole/ICV)	62/83 (75%)
Endoscopic abnormality, n (%) [among 83]	47 (57%)
Polyps	27 (57% of those with abnormality)

BMI: body mass index; ICV: ileocecal valve; SD: standard deviation.

1.2 Colonoscopy preparation and procedure

All patients adhered to a low-residue diet for at least three days. Preparation was fully compliant in 82 patients (86%) and partial in 13 (14%). The mean time elapsed between last liquid intake, and the recording was 5.06 hours (range 1–12; median 4.5 h); 64 patients (67%) completed their preparation 3–6 hours before the recording. Fifty-six patients (59%) used sodium picosulfate, 35 (37%) split polyethylene glycol, and 4 (4%) continuous polyethylene glycol.

Colonoscopy was performed in 83 patients (87%). Among these, 62 (75%) reached the caecal pole or ileocecal valve (complete colonoscopies); the remaining procedures were limited to more proximal colonic segments for technical or clinical reasons.

1.3 Endoscopic findings

Of the 83 patients who underwent colonoscopy, 47 (57%) had at least one endoscopic abnormality and 26 (31%) had no detectable lesion. Polyps were the most frequent finding, observed in 27 patients (57% of those with abnormality). Other findings included diverticula and areas of congestive or ulcerated mucosa.

1.4 Acoustic data

Across the 95 five-minute recordings, 33,837 intestinal sounds were labelled (mean 356 per recording; 71 ± 32 sounds per minute [range 19–175]). Mean sound durations were 62 ms for single bursts, 299 ms for multiple bursts and 545 ms for harmonic sounds (overall mean: 301 ms). The mean label-to-recording ratio (RLE) was 23% ± 16% [2–68%], corresponding to approximately 68 seconds of bowel sound per 5-minute recording.

2. Analytic findings

Multivariable logistic regression models were used to explore associations between aggregated acoustic features (method A: overall means; method B means per sound subtype) and selected binary

outcomes. Below, only associations reaching nominal statistical significance ($p < 0.05$) in at least one method are reported. 95% confidence intervals are provided for all significant associations. Given the exploratory design and the large number of tests performed, these findings should be considered hypothesis-generating.

2.1 Associations with clinical variables

Sex

Using method B, RMS was significantly higher in men (coefficient 5.58; 95% CI [0.825; 10.337]; p = 0.021) and envelope was higher in women (coefficient − 5.76; 95% CI [− 11.011; −0.511]; p = 0.032), suggesting greater effective amplitude in men and greater temporal variability in women.

Difficulty passing gas

With method A, RMS (coefficient − 14.99; 95% CI [− 29.205; −0.767]; p = 0.039) and envelope (coefficient 14.70; 95% CI [1.245; 28.157]; p = 0.032) were significantly associated with frequent difficulty passing gas. With method B, the same parameters remained significant — RMS (coefficient − 6.25; 95% CI [− 12.460; −0.047]; p = 0.048) and envelope (coefficient 6.91; 95% CI [0.222; 13.596]; p = 0.043) — and spectral contrast additionally emerged (coefficient − 1.30; 95% CI [− 2.522; −0.088]; p = 0.036). Overall, patients with frequent difficulty passing gas exhibited lower mean amplitude, greater temporal variability and more uniformly distributed spectral energy.

Body mass index

With method A, higher BMI was associated with lower RMS (coefficient − 4.38; 95% CI [− 8.388; −0.380]; p = 0.033) and higher envelope (coefficient 4.25; 95% CI [0.146; 8.349]; p = 0.043). Method B confirmed these associations (RMS: p = 0.019, 95% CI [− 3.283; −0.299]; envelope: p = 0.025, 95% CI [0.231; 3.354]), indicating that increasing BMI is associated with lower average sound amplitude and greater amplitude variability over time.

Other clinical variables

Arterial hypertension was associated with lower zero-crossing rate under method B (coefficient − 1.24; 95% CI [− 2.438; −0.048]; p = 0.041), suggesting a more stable acoustic signal. Abdominal percussion was associated with label count under method B (coefficient 0.58; 95% CI [0.019; 1.142]; p = 0.043), with tympanic abdomens showing more sound events. Additionally, waist circumference was associated with MFCC under method B (coefficient 0.35; 95% CI [0.009; 0.693]; p = 0.044). No significant correlations were found with IBD, thyroid disorders, diabetes, diarrhoea, constipation, stool consistency, bloating, abdominal pain, bleeding or stress level.

2.2 Associations with timing and preparation

Time since last liquid intake was consistently associated with zero-crossing rate: method A (coefficient 2.94; 95% CI [0.788; 5.099]; p = 0.008) and method B (coefficient 1.71; 95% CI [0.578; 2.836]; p = 0.003), indicating that bowel sounds become more rapidly oscillating as fasting time increases.

Bowel preparation quality was significantly associated with spectral contrast (method A: coefficient − 0.31; 95% CI [− 0.582; −0.035]; p = 0.028; method B: coefficient − 0.37; 95% CI [− 0.692; −0.055]; p = 0.022) and label count (method A: coefficient − 0.38; 95% CI [− 0.686; −0.076]; p = 0.015; method B: coefficient − 0.27; 95% CI [− 0.447; −0.088]; p = 0.004). An additional association was observed between better preparation and higher RLE under method B (coefficient 0.16; 95% CI [0.006; 0.310]; p = 0.042), suggesting that better-prepared colons, while producing fewer absolute sound events, occupy a proportionally greater share of the recording time.

2.3 Associations with endoscopic findings

Presence of any endoscopic abnormality

Under method B, the presence of at least one endoscopic abnormality was associated with lower RMS (coefficient − 5.01; 95% CI [− 9.341; −0.570]; p = 0.027) and higher envelope (coefficient 5.40; 95% CI [0.711; 10.086]; p = 0.024), indicating lower mean amplitude and greater temporal variability in patients with abnormal endoscopic findings.

Polyps

The presence of polyps showed the most striking associations. Under method A: RMS (coefficient − 11.77; 95% CI [− 23.067; −0.472]; p = 0.041) and envelope (coefficient 12.29; 95% CI [0.470; 24.111]; p = 0.042). Under method B: RMS (coefficient − 6.09; 95% CI [− 10.607; −1.572]; p = 0.008), envelope (coefficient 6.26; 95% CI [1.543; 10.970]; p = 0.009) and zero-crossing (coefficient 1.27; 95% CI [0.137; 2.405]; p = 0.028). Taken together, polyps were associated with a distinctive acoustic signature: lower mean amplitude, greater temporal variability and more rapid zero-crossings.

Other lesion types

Ulcerated and congestive mucosa showed more limited associations, primarily with label count. Diverticula did not exhibit robust or consistent correlations with the main acoustic parameters. These patterns were less pronounced than those observed for polyps.

Discussion

This monocentric pilot study demonstrates that standardized pre-endoscopic recordings of bowel sounds, analysed using multivariable logistic regression applied to a rich set of acoustic descriptors, capture clinically meaningful variation associated with patient characteristics and endoscopic findings. The identification of significant associations with sex, BMI and specific endoscopic lesions supports the hypothesis that intestinal acoustics can be transformed into quantitative biomarkers.

Patients in this cohort exhibited a mean of 71 bowel sounds per minute, exceeding the often-cited reference range of approximately 5–35 sounds per minute (13). Direct comparisons are difficult owing to the absence of a consensus definition of bowel sound events and the strong dependence of published estimates on recording method, abdominal site and classification scheme—considerations that underline the importance of methodological standardization before any normative thresholds can be established.

The robust association between sex and amplitude-related parameters is biologically plausible, as male and female patients differ in abdominal wall thickness, fat distribution and intra-abdominal volume, all of which affect sound generation and transmission. Similarly, the relationship between BMI and RMS/envelope likely reflects mechanical filtering by adipose tissue and geometrical differences in the abdominal cavity, which shape both the intensity and temporal envelope of bowel sounds.

The association between difficulty passing gas and specific acoustic features suggests that acoustic monitoring could provide an objective correlate of gas transit disorders—a symptom often poorly captured by conventional tests. However, because this variable is based on subjective self-report and was dichotomized for analysis, any acoustic 'signature' must be interpreted cautiously and confirmed in larger cohorts with more granular symptom scoring.

The most clinically provocative findings concern endoscopic outcomes. Significant associations between acoustic parameters and the presence of polyps or mucosal lesions suggest that structural changes may be accompanied by reproducible acoustic signatures—possibly reflecting alterations in motility, luminal gas-liquid interfaces or local compliance rather than a direct 'sound' of the lesion itself. These observations invite further mechanistic investigation combining acoustics with motility assessments.

The associations between preparation quality and acoustic features merit careful interpretation. A well-prepared colon contains less liquid and gas content, which mechanically alters the acoustic environment by reducing borborygmus production and modifying the resonance characteristics of the lumen. The observed acoustic changes associated with better preparation therefore likely reflect this direct physical effect, rather than a specific physiological signal. Future algorithms will need to account for preparation quality and fasting status as systematic covariates.

These results position intestinal sound analysis as a complementary, hypothesis-generating tool rather than a standalone diagnostic test at this stage. The high dimensionality of the acoustic data, the reliance on multivariable logistic regression without regularization or cross-validation, and the absence of multiple comparison correction together raise the risk of false-positive findings. Future work should shift from exploratory correlation analysis to prospectively powered predictive modelling focused on clinically actionable endpoints in multicentric cohorts.

Strengths and limitations

This study is, to our knowledge, among the first to integrate high-fidelity digital stethoscope recordings, detailed manual labelling, advanced acoustic feature extraction and multivariable logistic regression in a prospective pre-colonoscopy setting. Rigorous standardization of diet, preparation, recording protocol and abdominal site provides a reproducible methodological framework. The collaboration with data engineers enabled handling of the high-dimensional acoustic dataset and implementation of complementary aggregation strategies.

Key limitations include: (1) a convenience sample of 95 patients from a single centre, limiting statistical power and external validity; (2) absence of multiple comparison correction, which raises the type I error rate across the large number of tests performed; (3) no cross-validation, train/test split or regularization, increasing the risk of overfitting; (4) single-observer labelling without formal inter-observer reproducibility assessment; (5) a recording device originally validated for cardiac auscultation; (6) absence of external physiological references (manometry, transit studies), precluding mechanistic inference; and (7) the dietary and preparation confounders, only partially controlled.

Conclusion

In this monocentric pilot study, pre-endoscopic bowel sound recordings acquired with a modified digital stethoscope and analysed using multivariable logistic regression yielded acoustic features nominally associated with sex, BMI and several endoscopic outcomes, including colonic polyps and mucosal lesions. Preparation quality and fasting time also showed consistent acoustic correlates. Given the exploratory design, the absence of multiple comparison correction and the lack of external validation, these findings should be regarded as hypothesis-generating. Larger, multicentric and externally validated studies are required before intestinal acoustic analysis can be integrated into routine clinical decision-making in gastroenterology.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to a confidentiality agreement signed with Digehealth, but are available from the corresponding author on reasonable request.

Declarations

Author Contributions

K. Bouslama: Conceptualization, Data collection, Sound labelling, Formal analysis, Writing - Original Draft.

A. Nakhli: Supervision, Writing - Review & Editing.

Digehealth data engineers: Software, Acoustic feature extraction, Statistical modelling support.

All authors reviewed and approved the final manuscript.

Competing interests

N.G. Abassi reports a relationship with Digehealth that includes board membership and equity or stocks; Digehealth also provided the modified digital stethoscope and technical support used in this study under a confidentiality agreement. The remaining authors declare no competing interests.

Competing Interests

This study was conducted in collaboration with Digehealth, a Swiss startup developing a portable device for continuous intestinal sound monitoring. Digehealth provided the modified digital stethoscope, technical support and access to data engineers who contributed to acoustic feature extraction and model implementation. A confidentiality agreement was signed between the academic team and Digehealth. The authors declare no other conflicts of interest.

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This study received no dedicated financial support from public funding agencies, commercial entities, or non-profit organizations. The modified digital stethoscope and technical assistance for acoustic feature extraction were provided in kind by Digehealth (Zurich, Switzerland) under a confidentiality agreement. No monetary compensation was received by any author in connection with this research. The views and conclusions expressed in this manuscript are those of the authors alone and were not influenced by any external party.

Nour Ghalia Abassi reports a relationship with Digehealth that includes board membership and equity or stocks. All other authors declare no financial or personal relationships with Digehealth or any other entity that could have influenced the conduct or reporting of this study.

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to a confidentiality agreement signed with Digehealth, but are available from the corresponding author on reasonable request.

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Figures



Figure 1

Modified Littmann CORE digital stethoscope

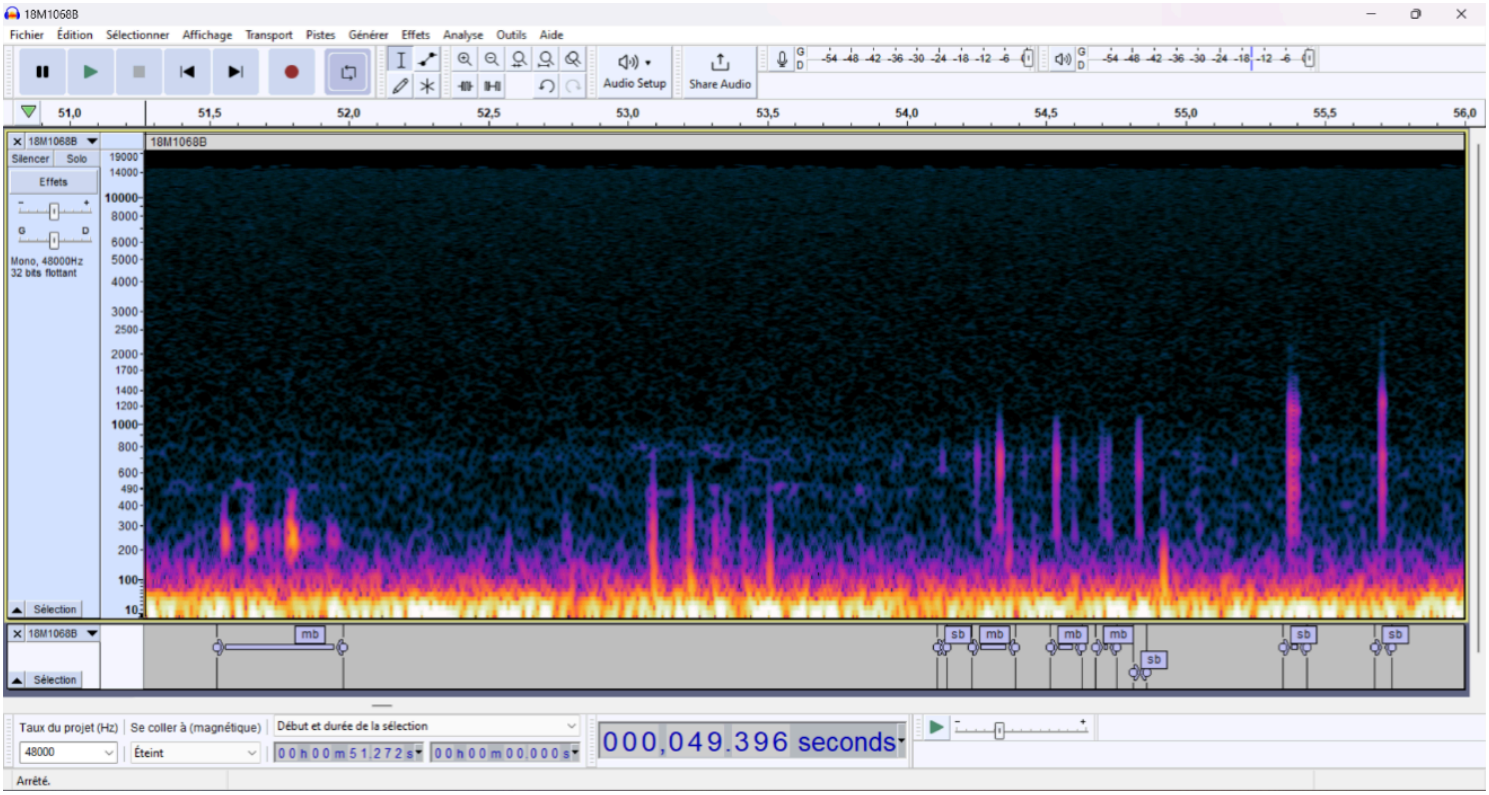


Figure 2

Spectrogram of the [51 s 252 ms; 55 s 987 ms] segment of recording 18M1068B, amplified and labelled.

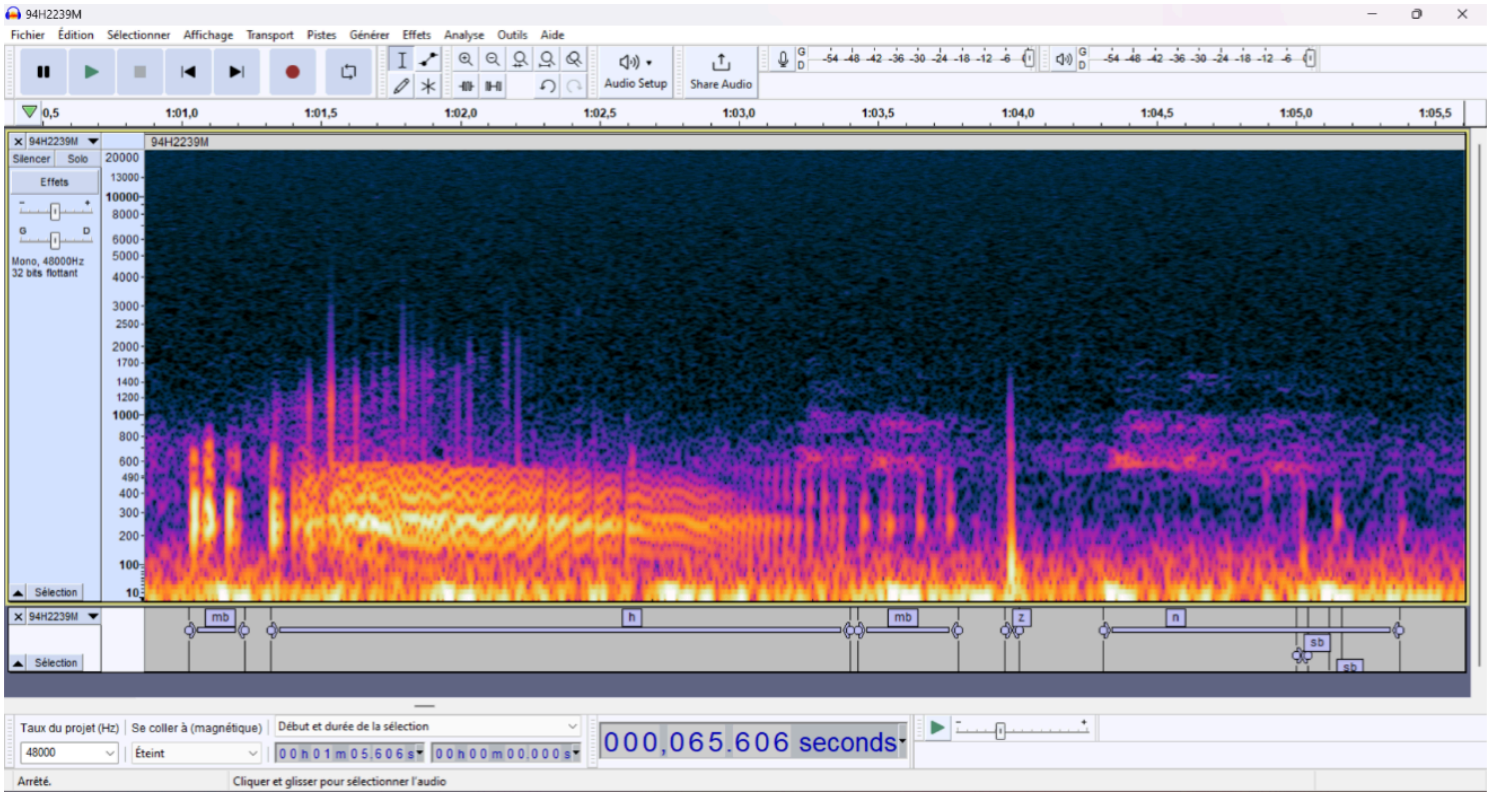


Figure 3

The different types of recorded sounds – single burst [sb]; multiple burst [mb] ; harmonic sound [h] ; surrounding noise artifact[n] ; stethoscope or digital artifact [z].