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RESEARCH ARTICLE

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Relationship between noise levels and intensive care patients' clinical complexity: An observational simulation study

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Abstract

Background: Noise pollution in intensive care units is a relevant problem, associated with psychological and physiological consequences for patients and healthcare staff. Sources of noise pollution include medical equipment, alarms, communication tools, staff activities, and conversations.

Aims: To explore the cumulative effects of noise caused by an increasing number and type of medical devices in an intensive care setting on simulated patients with increasing clinical complexity. Secondly, to measure medical device alarms and nursing activities' sound levels, evaluating their role as potentially disruptive noises.

Study Design: Observational simulation study (reported according to the STROBE checklist). Using an electronic sound meter, the sound levels of an intensive care room in seven simulated clinical scenarios were measured on a single day (09 March 2022), each featuring increasing numbers of devices, hypothetically corresponding to augmented patients' clinical complexity. Secondly, noise levels of medical device alarms and specific nursing activities performed at a distance of three meters from the sound meter were analysed.

Results: The empty room's mean baseline noise level was 37.8 (±0.7) dBA; among the simulated scenarios, noise ranged between 45.3 (±1.0) and 53.5 (±1.5) dBA. Alarms ranged between 76.4 and 81.3 dBA, while nursing tasks (closing a drawer, opening a saline bag overwrap, or sterile packages) and speaking were all over 80 dBA. The noisiest activity was opening a sterile package (98 dBA).

Conclusion: An increased number of medical devices, an expression of patients' higher clinical complexity, is not a significant cause of increased noise. Some specific nursing activities and conversations produce higher noise levels than medical devices and alarms. This study's findings suggest further research to assess the relationships between these factors and to encourage adequate noise reduction strategies.

Relevance to Clinical Practice: Excessive noise level in the intensive care unit is a clinical issue that negatively affects patients' and healthcare providers' well-being. The increase in baseline room noise from medical devices is generally limited. Typical nursing tasks and conversations produce higher noise levels than medical devices and alarms. These findings could be helpful to raise awareness among healthcare professionals to recognize noise sources. The noisiest components of the environment can be modified by staff behaviour, promoting noise reduction strategies and improving the critical care environment.

KEYWORDS
clinical complexity, critical care, intensive care unit, noise, sound

1 | INTRODUCTION

Noise pollution in the Intensive Care Unit (ICU) is a highly relevant and recurrent issue that may lead to harmful short- and long-term psychological and physiological consequences for patients and healthcare professionals.[1,2] For hospitals, limits for sound pressure levels have been suggested by the World Health Organization (WHO), 35 A-weighted decibels (dBA)[3] and by the US Environmental Protection Agency (USEPA), 45 dBA at daytime and 35 dBA overnight.[4] Despite the age of these two references, a recent systematic review reported that these institutions are the pioneer in this field and are widely used as reference values for hospital noise.[5] Sound levels in the ICU are continuously above recommended levels, with studies reporting average noise levels between 46 and 66 dBA and peak levels exceeding 80 dBA.[6–8] Therefore, maintaining hospital-recommended sound limits in the ICU setting is often challenging.[9]

Causes of noise pollution in the ICU are multiple and may include medical equipment, alarms, communication tools, staff activities and conversations, with sound levels greater than 75 dBA.[6,9,10] Monitoring devices, mechanical ventilators, infusion pumps and other life-supporting equipment are essential for the high level of care provided in the ICU setting. It is reasonable to argue that, in this setting, the number of medical devices used directly relates to the patient's clinical complexity. Thus, the main hypothesis of this research is that increased patient clinical complexity yields a greater use of medical devices and requires more staff activities that may further increase the environmental noise levels.

What is known about the topic

- Noise pollution in the Intensive Care Unit (ICU) is a relevant problem that may cause short and long-term psychological and physiological consequences for both patients and healthcare professionals.
- Sound levels in the ICU are constantly above the World Health Organization (WHO) and the US Environmental Protection Agency (USEPA) recommended levels.
- Previous studies identified medical equipment, alarms, communication tools, staff activities and conversations as the main causes of noise pollution in the ICU.

What this paper adds

- The number of medical devices used, theoretically corresponding to an increased patient clinical complexity, is not directly correlated to the noise level increase in an ICU setting.
- Some frequently performed nursing activities and staff talking were measured, confirming their role as a source of disruptive noises, with peak levels exceeding medical device alarms.
- The relationship between patients' critical illness, number and type of medical devices, and healthcare staff interventions requires further research to assess the impact on noise levels and to encourage noise reduction strategies.

2 | BACKGROUND

Previous investigations on the sound levels in general and surgical ICUs addressed the effects of noise on patients and staff, their sources and possible strategies to reduce them. Patients discharged from the ICU describe noise and disrupted sleep as negative experiences.[1,11,12] High noise levels impact patients' sleep quality and often require supplemental sedation, with the risk of developing anxiety, delirium and other physiological and psychological consequences, thus increasing hospital length of stay, mortality and long-term sequelae.[8,11,13–16]

Long-term exposure to high-level noise also affects healthcare workers, inducing cardiovascular responses, such as tachycardia and hypertension, headaches, anxiety, irritation, fatigue, stress and even job dissatisfaction and burnout.[17–19] Excessive noise levels may interfere with clinicians' ability to concentrate, increasing the risk of potential errors.[5,7,17] Furthermore, a noisy environment has been identified as a potential distractor that limits interaction between healthcare providers and patients, affecting the auditory capacity of physicians and nurses[2,20]; notably, to be heard, speech levels must exceed the ambient sound level by 15 decibels.[21,22] During the SARS COVID-19 pandemic, the co-presence of a noisy environment and personal protective equipment (facial masks, hoods and reusable respirators) further limited the ability to speak and hear.[23,24]

While most studies on noise pollution in the ICU setting deal with general environmental noise, information about the sound levels generated by increasing numbers of specific sources is lacking.

3 | AIMS

The present study sought, firstly, to assess the relationship between the number and type of medical devices used in simulated patients with increasing clinical complexity and the resulting noise levels in an ICU setting. Secondly, to measure the sound levels produced by the devices' alarms and typical ICU activities (nursing tasks and speaking) to assess their role as potentially disruptive noises.

4 | DESIGN AND METHODS

4.1 | Design and setting

This observational study was performed in a simulated clinical ICU setting in a new unit set up and used during the COVID-19 pandemic. During the study period, this unit was unused, and one room was dedicated to training and on-site simulation for newly hired nurses and intensivists. Noise levels were measured inside a two-bed ICU room (42.8 m^2) equipped with a single bed and an AL S-1000 simulation mannequin (Gaumard Scientific, Coral Gables, FL, USA). According to our region's standards, the recommended bed space is 20 m^2 for single-bed ICU rooms or 15 m^2 in case of multiple-bed rooms. All measurements were performed on a single day (09 March 2022) in the Fausto Gresini ICU Simulation room at Giorgio Gambale Training Centre, Maggiore hospital Carlo Alberto Pizzardi, Bologna (Italy). The study is reported according to the STrengthening the Reporting of OBservational Studies in Epidemiology (STROBE) checklist for observational studies (Supplementary File S1).

4.2 | Data collection tools and methods

Environmental noise levels were measured with a noise-meter application (Decibel X, SkyPaw Co. Ltd., Hanoi, Vietnam), installed on a dedicated tablet (Lenovo Table M10 HD, Lenovo, Quarry Bay, Hong Kong). As shown in Figure 1, the tablet was positioned near the mannequin's head at the ear level to gain insight into the patient's experience of noise levels exposure in the ICU; this location allowed to measure the noise directly, as perceived by a patient, limiting reflection, absorption and reverberation of noise on different surfaces, which could have affected the measurement. The Decibel X app supports the most used frequency weighting filters. Sound pressure levels

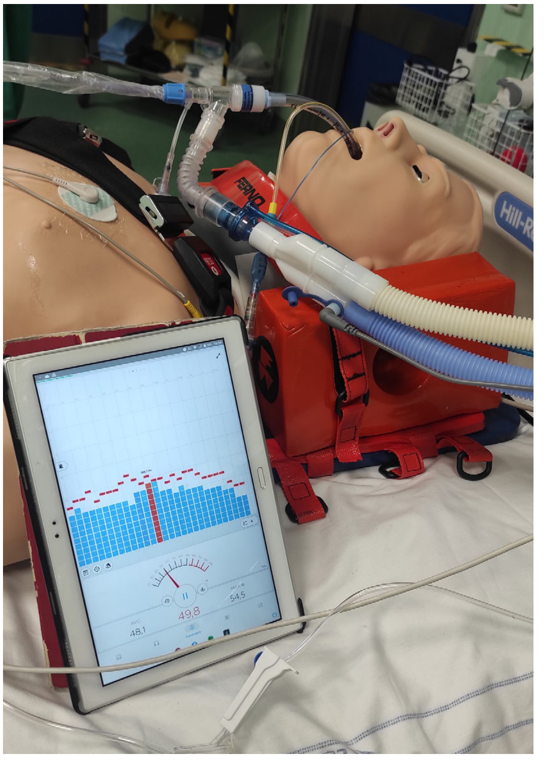

FIGURE 1 Simulation scenario, with noise meter app positioned at the height of the mannequin's ears.

were measured using the A-weighted scale, the most used filter for measuring loud noise. The A-filter attenuates low frequencies and has the same sensitivity to sound at different frequencies as the average human ear. Every measurement lasted 3 min, with the response time set to "fast" mode (one measure every 200 ms, five measures per second). The collected data included the essential information recommended by Wallis et al. to report accurate measurement and documentation of environmental noise assessment in hospitals (location of the measuring device, sampling intervals, equipment manufacturer and model, calibration process, and time constant and frequency weighting).[25] Recorded data were saved in the tablet and exported as comma-separated values files for subsequent analysis.

Before the simulation study, the sound meter app was calibrated by pointing the tablet microphone toward a speaker, at a distance of one meter, while playing a calibration tone at 94 dB (measured through another pre-calibrated device).

The first step of the study was to measure the background noise levels of an empty ICU room set up for admission, with no patients and healthcare providers. Potentially noise-producing elements were medical devices in standby mode (ventilator, monitors, and infusion devices) and the standard surrounding environment, including air conditioning and room ventilation systems. Subsequent measurements were performed in seven simulated scenarios involving increasing numbers of medical devices: the different types of devices were added to replicate the device changes that occur when a patient becomes more critically ill. Based on this assumption, the increased number of devices was considered the expression of increased levels

TABLE 1 Simulated clinical scenarios and medical devices used.

Scenario (number of devices used)	Medical devices used
Empty room	Standard ICU environment: medical devices in standby mode, air conditioning, and room ventilation systems
Case #1 (5)	Basic monitoring, 1 infusion pump, 2 syringe infusion pumps and Venturi oxygen mask (6lt-40%)
Case #2 (6)	Basic monitoring, 1 infusion pump, 2 syringe infusion pumps, 1 enteral feeding pump and HFNC (50lt-FiO2 50%)
Case #3 (6)	Basic monitoring, 1 infusion pump, 2 syringe infusion pumps, 1 enteral feeding pump and non-invasive ventilation with a full-face mask
Case #4 (8)	Basic monitoring, 1 infusion pump, 3 syringe infusion pumps, 1 enteral feeding pump, invasive mechanical ventilation and active humidification
Case #5 (12)	Basic monitoring, advanced haemodynamic monitoring, 1 infusion pump, 5 syringe infusion pumps, 1 enteral feeding pump, invasive mechanical ventilation, active humidification and 1 chest drainage connected to wall suction
Case #6 (12)	Basic monitoring, advanced haemodynamic monitoring, 1 infusion pump, 5 syringe infusion pumps, 1 enteral feeding pump, invasive mechanical ventilation, active humidification and CRRT
Case #7 (12)	Basic monitoring, advanced haemodynamic monitoring, 1 infusion pump, 5 syringe infusion pumps, 1 enteral feeding pump, invasive mechanical ventilation, active humidifier and ECMO

Abbreviations: CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; HFNC, high-flow nasal cannulae; ICU, intensive care unit.

of patients' clinical complexity. Table 1 reports the medical devices featured in every simulated clinical scenario (i.e., the seven case registrations), while Supplementary File S2 details the model and manufacturer of the medical devices used during the registration sessions. During these measurements, all infusion devices were turned on at predefined rates (5 mL/h for syringe pumps, 42 mL/h for both infusion and enteral feeding pumps); mechanical ventilation was set in controlled mode, with a respiratory rate of 15/min and a tidal volume of 350 mL (adequate for the mannequin). Continuous Renal Replacement Therapy (CRRT) and Extracorporeal Membrane Oxygenation (ECMO) devices were set to values similar to those used during clinical use. No other noise patterns ordinarily present in the ICU were produced (i.e., healthcare staff activities, speaking, telephones, or alarms).

The study's second phase measured the noise levels related to medical device alarms and some typical ICU nursing tasks. The latter included one single nurse opening a sterile package, the plastic overwrap of a saline bag and closing a drawer; staff speaking involved three people. These activities were performed in the most complex simulated scenario (case #7) at a distance of three meters from the mannequin's ear, equivalent to one meter from the footboard of the ICU bed, which is the typical position of our trolleys. This reproduces the working habits of our nursing staff. Even considering that the ICU environment is multi-professional, this part of the study evaluated the noise related to some nursing activities because ICU nurses represent the healthcare category, working 24 h a day in close proximity to the patients.

4.3 | Bias

Using a single tablet prevented differences related to different microphone sensitivity, which are possible when using different electronic devices. All case registrations occurred at the same location, on the same day and by a single group of researchers. Moreover, the simulation centre is in an area not dedicated to clinical activities, so we can assume that the measured baseline noise was not influenced by external noises and corresponded to the actual value.

4.4 | Ethical considerations

This study was conducted in a simulation setting. Ethical board approval is not required at our institutions for studies not involving human patient data. Nonetheless, the project was endorsed and approved by the Critical Care Nursing Master Course Director (Professor B.G. Samolsky Dekel, University of Bologna, Bologna, Italy).

4.5 | Data analysis

Noise levels, measured as A-weighted decibels (dBA), are reported as continuous variables (mean, standard deviation, minimum and maximum values). The intensity of alarms and other disruptive noises is reported considering the peak level detected by the DecibelX application. Data were analysed with Microsoft Excel, version Microsoft Office Professional Plus 2019 (Microsoft Corporation, Redmond, WA, USA).

5 | RESULTS

5.1 | Clinical complexity and sound levels

Eight subsequent sound level registrations were performed in the first part of the study, exploring the effects of noise relating to medical devices matched with an increased level of a patient's critical illness. Table 1 reports type and number of the medical devices featured in each simulated clinical scenario case; scenarios #1, #2 and #3 feature a Level 2 patient, while other scenarios feature a Level 3 patient.[26] Table 2 reports the mean (±DS), minimum and peak noise levels

TABLE 2 Noise levels measured in the simulated ICU scenarios.

	Noise level, dBA			Δ dBA		
Scenario	Mean (±SD)	Min	Peak	Empty room	WHO	USEPA
Empty room	37.8 (0.7)	36.1	44.1	-	2.8	−7.2
Case #1	47.3 (0.4)	45.8	50.1	9.5	12.3	2.3
Case #2	53.5 (1.5)	51.0	57.7	15.7	18.5	8.5
Case #3	46.3 (2.0)	43.0	67.4	8.5	11.3	1.3
Case #4	46.9 (2.8)	42.6	54.5	9.1	11.9	1.9
Case #5	48.1 (2.6)	44.8	55.9	10.3	13.1	3.1
Case #6	51.3 (1.4)	45.4	68.2	13.5	16.3	6.3
Case #7	45.3 (1.0)	43.2	50.1	7.5	10.3	0.3

Note: Δ, absolute difference of noise level from the WHO (35 dBA) and USEPA (45 dBA, daytime) recommended values.
Abbreviations: dBA, A-filtered decibel; Max, maximum value; Min, minimum value; SD, standard deviation; USEPA, US environmental protection agency; WHO, world health organization.

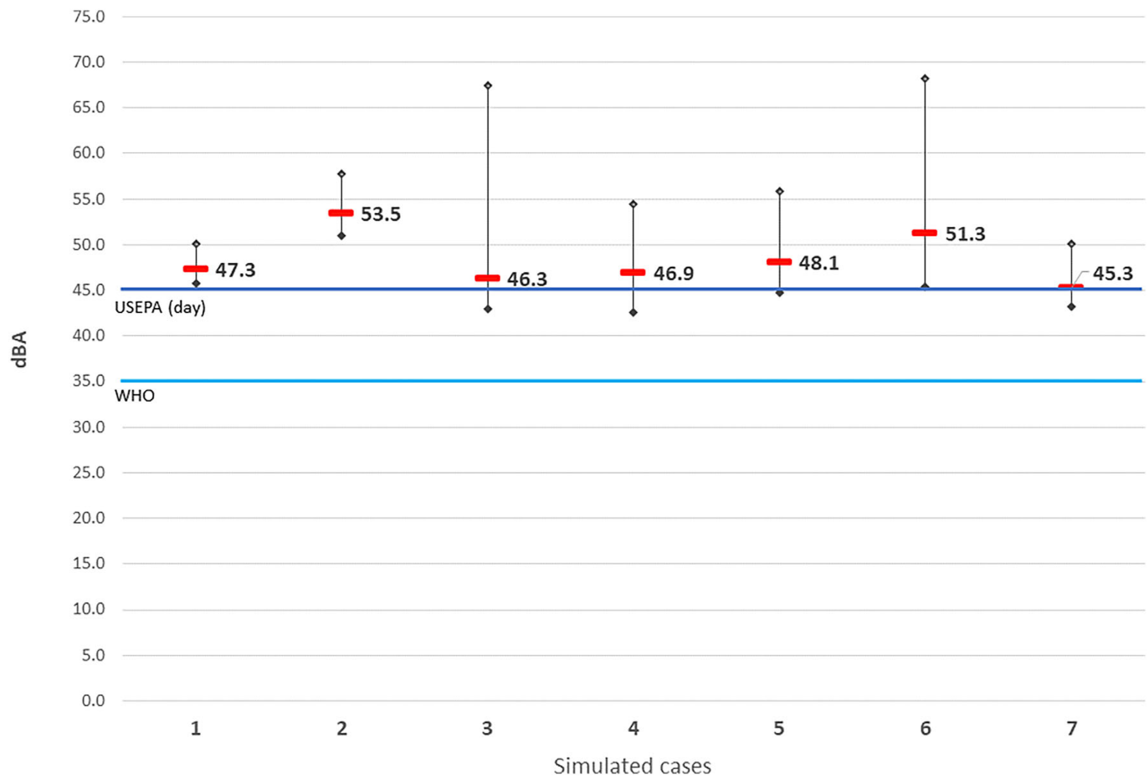

FIGURE 2 Average, minimum and peak noise levels measured in simulated ICU patients. The two horizontal lines report the World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) recommended noise levels in hospitals of 35 and 45 dBA (during daytime), respectively. All values are reported in A-filtered decibels (dBA). ICU, intensive care unit.

recorded in each scenario; it also reports, respectively, the difference (Δ) between the registered cases' noise levels and the empty room, and the WHO (35 dBA) and USEPA (45 dBA) recommended noise levels for daytime. Notably, decibels measure the sound level on a logarithmic scale: a three-decibel increase represents a doubling of the sound intensity, while ten decibels represent a ten-fold increase. Figure 2 depicts the measured noise levels, compared with the WHO and USEPA's recommendations. The mean noise level found in the empty ICU room was 37.8 (±0.7) dBA. In the seven simulated clinical scenarios, noise levels ranged between 45.3 (±1.0, case #7) and 53.5 (±1.5, case #2) dBA, with a 19.8%–41.5% increase against the empty room noise level, respectively. The original hypothesis of this study, that noise levels rise in relation to an increasing number of employed devices aligned with patient critical illness, is not supported by the data collected. The most complex scenarios (cases #6 and #7, both matched with a Level 3 patient treated with CRRT and ECMO devices,

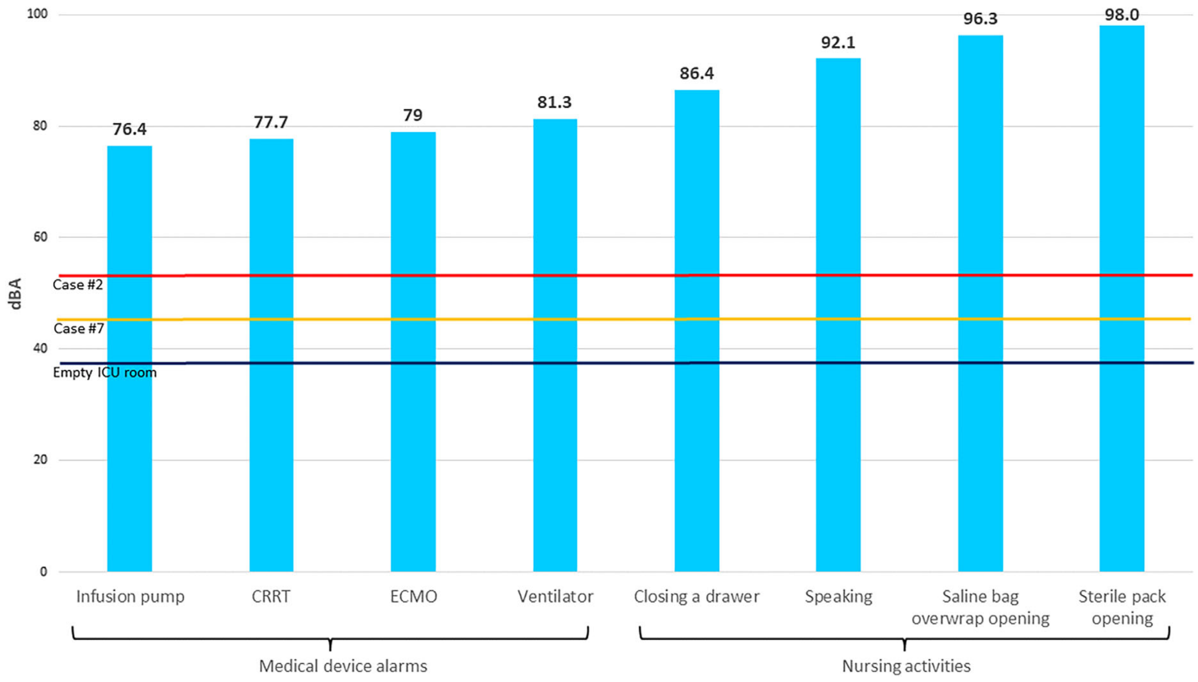

FIGURE 3 Noise levels generated by device alarms and nursing activities. Horizontal lines report the noise level of empty ICU room, less noisy scenario (#7) and noisier scenario (#2). All values reported in A-filtered decibels, dBA. CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit.

respectively) recorded noise levels lower than low-complexity scenarios simulating a Level 2 patient with a limited number of devices.

At all times, noise levels exceeded the WHO-recommended hospital noise level; in particular, exceeding noise-level percent ranged from 8.0% in the empty room to 52.9% in case #2. Compared with the USEPA daytime noise-level recommendations, we found that exceeding values was mostly limited. Notably, the empty room showed an inferior noise level of 16%; cases #2 and #6 showed an exceed of 18.9% and 14.0%, respectively, while in the resting cases, exceed was between 0.7% (case #7) and 6.9% (case #5).

5.2 | Medical device alarms and nursing activities

The second phase of the study registered the sound levels originating from device alarms and ICU nursing activities. Figure 3 depicts the peak sound levels generated by medical device alarms and nursing activities, from the lowest to the highest noise level. Figure 3 also reports, for comparison, the sound levels of the empty room, and those of the cases with the highest and lowest sound levels (cases #2 and #7, respectively). Alarms' mean sound levels ranged between 76.4 and 81.3 dBA, while nursing tasks and talking were all over 80 dBA. The activity that produced the highest noise level was opening a sterile package (98.0 dBA).

Compared with the empty room, alarms variably increased the baseline noise level between 102.1% and 115.1% and staff activity between 128.6% and 159.3%; compared with case #2, alarms increased noise level between 42.8% and 52.0% and staff activity between 61.5% and 83.2%; and, compared with case #7, alarms increased noise level between 68.7% and 79.5% and staff activity between 90.7% and 116.3%.

6 | DISCUSSION

This study performed in an ICU setting on simulated patients found that an increased number of medical devices does not directly relate to the amount of noise level. The initial hypothesis assumed that an increasing amount of medical equipment used may be an expression of the patient's increased clinical complexity and, consequently, may lead to an increase in the measured noise levels in an ICU setting. Conversely, average noise levels registered in simulation cases with a relatively low number of medical devices used were higher than in other cases. Device number was not an indicator of noise levels, and some medical devices produce higher noise levels, even if they are not related to an augmented clinical complexity. For example, the high-flow nasal cannulae (HFNC) system used in case #2 produced a noise level higher than that measured in cases with a greater number of devices, including organ support systems such as CRRT or ECMO (e.g., case #2, 6 devices vs. cases #5, #6 and #7, with 12 devices each). In all simulated cases, mean noise levels exceeded the WHO and USEPA daytime recommendations. All device alarms induced high noise levels, but interestingly, specific nursing activities (closing a drawer, opening a saline bag overwrap, or a sterile package) and speaking markedly increased these levels, even when performed at a distance of three meters from the mannequin, exceeding the alarms with peak values ranging over 80 dBA. It was reasonable to argue, and thus to further investigate, whether the devices' alarms, more than the actual number of devices, along with nursing activity, may relate to increased noise levels in ICU patients with greater clinical complexity.

High sound pressure levels in the ICU are a recognized issue. Literature studies report average noise values between 46 and 66 dBA, with peaks between 59 and 91 dBA, both in general, surgical, and even SARS-COVID-19 dedicated ICUs, far exceeding the noise levels recommended for hospitals.[10,18,27–34] Medical devices produce low-frequency and repetitive sounds, resulting in unavoidable noise 24 h a day. Moreover, most of the noise in the ICU is generated from sources immediately adjacent to the patient's ears, maximizing its adverse effects.[9,22] Despite the numerous life-supporting devices in the ICU, the noise they generate when their alarms are turned off seems limited, thus their role in increasing the baseline noise level.[18,22] Our findings partially agree with this assertion, as we found an increase in the various simulated cases compared with an empty ICU room. Previous studies reported sound levels exceeding 50 dBA in unoccupied ICU rooms, suggesting that most of the baseline noise level is caused by sources like air conditioning, heating and ventilation systems, refrigerators and pneumatic tube systems.[6,18,22] Respiratory-support devices like oxygen masks with flow rates >10 L/min and HFNC generate continuous additional high noise (>60–65 dBA).[6] Similar results were found in #case 2 (the noisiest scenario in this study), in which six medical devices, including HFNC, were used.

Darbyshire & Young conducted a series of 24-h noise measurements in a British ICU, both within the central monitoring station and adjacent to patients. This study found that average sound levels always exceeded 45 dBA and, for half of the registration time, ranged between 52 and 59 dBA; values decreased after evening handovers, reaching a minimum of 51 dBA at 4 a.m. The authors concluded that the WHO's hospital sound level recommendations could only be reached in laterally organized ICU rooms and by switching off all the equipment.[9] Noise attenuation in the ICU may be achieved by modifying the architectural configuration through structural interventions or layout rearrangements. Single-bed rooms and external monitoring stations yield less disruptive noises.[35,36]

The medical devices' alarms are another category of noise generators in the ICU. Monitoring systems and ventilator alarms account for 80% of the so-called disruptive noises in the ICU; these devices produce short and high-intensity noises that disrupt patients' sleep.[22] A recent observational study conducted in four Dutch ICUs reported an average of 170 alarms per day/per bed.[37] Electronic alarms have a more significant adverse effect on sleep than other noise sources, with peak levels exceeding 80 dBA.[6] Furthermore, it has been estimated that about 90% of the alarms are false positives and contribute to an increase in average sound pressure levels of 60 dBA at the patient's bedside.[22,38] Indeed, our findings show that device alarms may increase the sound level of an empty ICU room by over 40 dBA. Alarms are an essential and constant feature of the ICU; given their role as disruptive noise generators, future research should evaluate strategies to limit their presence next to the patient's bed or to use single-bed ICU rooms with external monitoring stations.

Finally, another crucial disruptive-noise source category in the ICU is represented by staff and nursing activities. Among the latter, it has been reported that walking in the patients' room and in nearby corridors may generate up to 84 dBA, healthcare staff conversations may account for 74 dBA and suction devices for 64 dBA.[39] Patients described these activities as generators of high noise levels, also commenting that noise arising from other patients and recurrent alarms were highly disruptive.[39] Staff conversations unrelated to the patient's care are another frequent noise source, occupying between 24% and 62% of the measurements, with peak levels similar to those of electronic alarms.[6,18,36] In a study on factors influencing sleep quality in the ICU, 79.7% of patients reported as stressors the healthcare staff talking, joking and discussing issues in loud voices, and 68.9% considered it very stressful.[40] Our findings confirm that staff speaking is among the highest staff activity noise levels (92.1 dBA).

Unlike other studies on noise generators in the ICU, this research selectively measured the noise generated during a series of frequently performed nursing activities, highlighting their role as a source of disruptive noises. For example, opening a saline bag or a sterile pack generated a noise level of over 96 dBA, increasing the sound level of an empty ICU room by approximately 50 dBA. This study's approach to evaluating noises generated by frequently performed nursing activities and not only by the most evident sources supports the idea that noise generation in the ICU is a multifarious and dynamic issue that needs further exploration. The reproducibility of such investigations may help increase the awareness of ICU personnel about such a relevant issue, identifying the noisiest activities and promoting proactive strategies to minimize them.[1,32] Improving disruptive noise levels in the ICU may include better organization of daytime care activities and preparing care material and infusions in dedicated space at a distance or outside the patients' area while complying with sterile procedures to minimize the risk of infection. In addition, earplugs, noise-cancelling headphones, or other non-pharmacologic noise reduction tools to reduce noise exposure overnight, particularly loud conversation, may increase patient satisfaction and reduce the risk of delirium while providing a safer working environment for healthcare providers.[1,21,29,41]

6.1 | Strength and limitations

This study was held in an ICU setting on a simulated patient. The strongest element of this study is that it was performed in a real ICU setting, in an ICU used during the COVID-19 pandemic. During the study period, this unit was unused and dedicated to training and on-site simulation. Even if this setting may not represent a real ICU because of the absence of staff, patients and other noise sources, the baseline noise (air conditioning, ventilation and devices in idle mode) could be considered real. The simulation results are sometimes only reliable approximations, and quantifying all the variables that affect the explored conditions may be challenging. Furthermore, simulation studies need appropriate pseudorandom generators of independent and uniformly distributed variables, and appropriate analysis of simulation output data.[42] This simulation enabled an experimental model affecting the entire system, eliminating the need for costly trial-and-error methods and flexible introduction of variables and changing the natural environment. As opposed to other real-context observational studies, a point of strength of this research is the controlled and cumulative introduction of a greater number and type of noise-generating elements, which would have not been possible in a real ICU setting. Nonetheless, the advantages of this simulation study, aside from limited time and cost consumption, reside in its reproducibility: the use of a tablet-installed noise-meter application proved to be feasible and cost-effective. As previously reported, using such modern applications rather than professional noise meters may improve the generalizability of noise investigations in a broader range of clinical settings.[28,30,32,33]

6.2 | Implications and recommendations for practice

Measuring noise levels in clinical areas, even with simple and accessible devices such as tablets, mobile phones, or smartwatches with dedicated apps, may contribute to identifying noise-generating sources and activities. Healthcare professionals should be increasingly aware of these issues, encouraging noise reduction strategies to facilitate lower volumes from other clinical areas, such as nursing stations, where conversations not related to medical issues may occur, which have been identified as important contributors to noise levels.

7 | CONCLUSION

The use of an increased number of medical devices, along with patients' clinical complexity of care, is not a significant cause of increased noise levels within the ICU. Everyday nursing activities may often produce noise levels higher than device alarms. Increased patients' critical illness requires a greater number of different medical devices and healthcare staff interventions, representing a vicious cycle of noise production. The relationships between these factors require further dedicated research to establish adequate preventive strategies.

AUTHOR CONTRIBUTIONS

All authors made a significant contribution to the conception, study design, data collection, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work.

Guglielmo Imbriaco: Conceptualization, Investigation, Methodology, Project Administration, Writing—Original draft preparation, Writing—Review & Editing; **Martina Capitano**: Conceptualization, Investigation, Writing—Original draft preparation; **Margherita Rocchi**: Conceptualization, Investigation, Writing—Original draft preparation; **Aglaja Suhan**: Conceptualization, Investigation, Writing—Original draft preparation; **Alice Tacci**: Conceptualization, Investigation, Writing—Original draft preparation; **Alessandro Monesi**: Investigation, Resources, Data curation; **Stefano Sebastiani**: Conceptualization, Resources, Supervision, Writing—Review & Editing; **Boaz Gedaliahu Samolsky Dekel**: Formal Analysis, Methodology, Supervision, Validation, Writing—Review & Editing.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This is a simulation study. Ethical board approval is not required at our institutions for studies that do not involve patient data.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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