

Original Research Article

Efficacy of music therapy on pain reduction during arterial blood gas analysis: an open-label randomized controlled trial

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ABSTRACT

Background: Arterial blood gas (ABG) sampling is commonly associated with procedural pain and anxiety. Nonpharmacological approaches such as music therapy may attenuate pain without impacting workflow or safety. Objectives were to evaluate whether music therapy reduces pain during ABG sampling compared with standard care, and to assess effects on number of puncture attempts and procedure duration.

Methods: Open-label, parallel-group randomized controlled trial. General medicine wards of a tertiary-care teaching hospital in Eastern India (3-month enrollment). Adults (≥ 18 years) requiring ABG sampling who were alert or verbally responsive (AVPU A/V). Participants were randomized (SNOSE) to music therapy via headphones during ABG (intervention) or standard care (control). Primary outcome was post-procedure pain using 0-10 numerical rating scale (NRS). Secondary outcomes were number of puncture attempts and procedure duration. Analyses used independent t-test and chi-square as appropriate ($\alpha=0.05$).

Results: Among 186 participants ($n=92$ music; $n=94$ control), mean NRS pain was lower with music (4.07 ± 2.08) versus control (5.11 ± 2.59); mean difference -1.04 (95% CI -1.72 to -0.36), $p=0.003$. First-attempt success was similar (77.2% vs 73.4%; $p=0.280$). Procedure duration distribution ($<30s$ / $30-60s$ / $>60s$) did not differ between groups ($p=0.890$).

Conclusions: Music therapy significantly reduced procedural pain during ABG without affecting success or duration. This feasible, low-cost intervention can be incorporated into routine nursing practice for procedural comfort. Nurses can lead implementation of music therapy during brief invasive procedures to improve patient experience without disrupting workflow.

Keywords: Music therapy, Arterial blood gas, Procedural pain, Nursing, Randomized controlled trial, Nonpharmacological analgesia

INTRODUCTION

Arterial blood gas (ABG) analysis is integral to assessing respiratory and metabolic status in acute care, yet arterial puncture can cause clinically meaningful procedural pain.¹ Effective, scalable strategies to minimize discomfort are a nursing priority and may enhance patient cooperation and overall care quality.² Numerous techniques have been explored to alleviate pain during invasive procedures, including local anesthetics,

distraction methods, and cognitive-behavioral interventions.³ However, the use of non-invasive interventions, such as acoustic stimulation through music, has gained attention due to its potential to reduce pain perception without the need for pharmaceutical agents. Music therapy, specifically, has been shown to provide significant pain relief in a variety of clinical settings, including during surgical procedures, labor and delivery, and even in pediatric populations undergoing blood draws.⁴⁻⁶ The mechanisms behind music's analgesic effect

are thought to involve both psychological and neurophysiological processes, including distraction, emotional regulation, and the release of endorphins.⁷ Music therapy-using structured listening to calming music-has shown analgesic benefits across clinical settings and has strong acceptability. However, evidence specific to adult ABG sampling is sparse.⁸ We conducted an open-label randomized controlled trial (RCT) to determine whether music therapy reduces ABG-related pain and to evaluate effects on puncture attempts and procedure duration.

METHODS

Design and setting

Open-label, parallel-group RCT conducted in general medicine wards of a tertiary-care hospital in Eastern India (AIIMS, Patna, India) over a period of 3 months (end of March 2024 to July 2024).

Participants

Adults (≥ 18 years) undergoing ABG for any indication who were alert or verbally responsive (AVPU A/V) were included and patients with known hearing impairment; emergencies precluding consent; refusal of consent were excluded.

Randomization and masking

Participants were randomized 1:1 using sequentially numbered, opaque, sealed envelopes (SNOSE) to intervention (music therapy) or control (standard care). Outcome assessors were not masked; pain was self-reported immediately post-procedure.

Intervention and control

Intervention arm: over-ear headphones delivering calming instrumental music during ABG sampling. Control arm: standard ABG procedure without music. All punctures followed aseptic precautions at radial, brachial, or femoral sites per clinician judgment.

Outcomes

Primary: (NRS, 0-10) pain immediately post-procedure. Secondary: number of puncture attempts; procedure duration categorized as <30s, 30-60s, or >60s. Pain categories were also described as mild (1-3), moderate (4-6), severe (7-10).

Data collection and statistical analysis

Data sources included direct observation, patient self-report, and procedural records. Continuous variables were summarized using mean $\pm$ SD or median (IQR). Between-group comparisons used independent t-test (primary outcome) and chi-square tests (categorical outcomes).

Two-sided $p < 0.05$ was considered significant. Analyses were performed in IBM SPSS v26.0.

Ethical approvals

The study adhered to the Declaration of Helsinki. Study protocol was approved by the Institutional Ethics Committee, AIIMS, Patna [Reference No.: AIIMS/Pat/IEC/2024/1212 dated 2nd March 2024] prior initiation of the study. Written informed consent was obtained from all participants

RESULTS

We enrolled 186 participants: 92 assigned to music therapy and 94 to standard care. Baseline characteristics (age, sex, puncture site) were comparable between groups (Table 1). Distribution of pain intensity categories (mild 1-3; moderate 4-6; severe 7-10) by group (Figure 1). Pain intensity distribution differed descriptively between groups: in the music group, 43.5% reported mild pain, 39.1% moderate, and 17.4% severe; in controls, 25.5% reported mild, 43.6% moderate, and 30.9% severe.

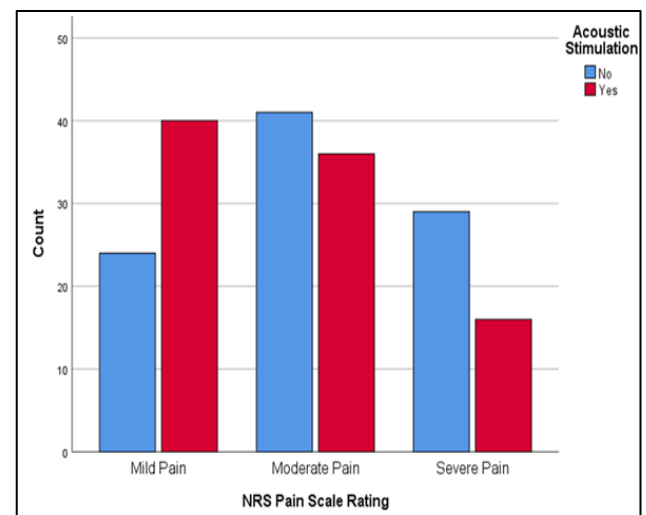


Figure 1: Distribution of NRS pain scale ratings in groups A and B.

The mean (SD) pain score in group A was 4.07 (2.08), which was lower than the mean score in group B at 5.11 (2.59). The mean difference was 1.04, with a 95% CI ranging from -1.72 to -0.36. This difference was statistically significant ($p = 0.003$) (Table 2).

In group A, in the majority of participants, 71 (77.2%), arterial puncture was successful on the first attempt, followed by 16 (17.4%) requiring two attempts, and 5 (5.4%) requiring three attempts. Similarly, in Group B, most participants, 69 (73.4%), arterial puncture was successful on the first attempt, 23 (24.5%) required two attempts, and 2 (2.1%) needed three attempts. The chi-square test showed no statistically significant difference between the two groups, with a $p = 0.280$ (Table 3).

In group A, 20 procedures (21.7%) were completed in less than 30 seconds, 35 (38.0%) took 30 to 60 seconds, and 37 (40.2%) took more than 60 seconds. Similarly, in group B, 19 procedures (20.2%) were completed in less than 30 seconds, 39 (41.5%) took 30 to 60 seconds, and 36 (38.3%) took more than 60 seconds.

The chi-square test showed no statistically significant difference between the two groups, with a $p=.890$ (Table 4). The primary outcome favored music therapy with a statistically and clinically meaningful reduction in pain. There were no significant between-group differences in first-attempt success or in procedure duration categories.

Table 1: Demographic details of participants in groups A and B, (n=186).

Variables	Categories	Group A, (n=92)	Group B, (n=94)
Age (in years)	≤ 20	8 (8.7 %)	7 (7.4 %)
	21-40	29 (31.5 %)	16 (17 %)
	41-60	30 (32.6 %)	32 (34 %)
	61-80	21 (22.8 %)	20 (21.3 %)
	> 80	4 (4.4 %)	19 (20.3 %)
Gender	Male	53 (57.6 %)	51 (54.3 %)
	Female	39 (42.4 %)	43 (45.7 %)
Site of arterial puncture	Radial	61 (66.3 %)	55 (58.5 %)
	Brachial	17 (18.5 %)	27 (28.7 %)
	Femoral	14 (15.2 %)	12 (12.8 %)

Table 2: Comparison of mean pain scores between groups A and B.

Groups	Mean pain score	Standard deviation	Mean difference	95% CI of the difference		P value
				Lower bound	Upper bound	
A	4.07	2.08	-1.04	-1.72	-0.36	0.003
B	5.11	2.59				

Table 3: Number of attempts required for successful arterial puncture in groups A and B.

Number of attempts for successful arterial puncture	Group A, (n=92)		Group B, (n=94)	
	N	%	N	%
One	71	77.2%	69	73.4%
Two	16	17.4%	23	24.5%
Three	5	5.4%	2	2.1%

Table 4: Duration of ABG procedure performed in groups A and B.

Duration of procedure (in seconds)	Group A, (n=92)		Group B, (n=94)	
	N	%	N	%
<30	20	21.7%	19	20.2%
30-60	35	38%	39	41.5%
>60	37	40.2%	36	38.3%

DISCUSSION

In this RCT of adults undergoing ABG sampling, music therapy reduced procedural pain without compromising efficiency or technical success. The magnitude of pain reduction (≈ 1 NRS point) aligns with meta-analytic estimates of music's analgesic effect across clinical contexts. Proposed mechanisms include attentional distraction, affective modulation, and engagement of descending inhibitory pathways. The study results demonstrated that participants in group A (acoustic stimulation) experienced significantly less pain compared to group B (standard care). The mean pain score was significantly lower in group A (4.07 ± 2.08) than in group

B (5.11 ± 2.59) ($p=0.003$). Although more participants in group A had successful arterial puncture on the first attempt (77.2% vs. 73.4%), and a similar proportion of procedures in both groups were completed in less than 30 seconds, these differences were not statistically significant ($p=0.280$ and $p=0.890$, respectively). Our findings support integrating nurse-delivered music interventions into routine ABG practice.

The impact of acoustic stimulation through music therapy on pain reduction observed in our study is consistent with findings from existing literature.^{6,9-10} A meta-analysis reported a mean pain score reduction of 1.13 across 97 studies, which closely aligns with our study's result of

1.04, underscoring the efficacy of music therapy in pain management.¹¹ However, contrasting findings were reported, where the effect of music therapy was not statistically significant and was comparable to the effects of mere distraction.¹² This discrepancy could be attributed to the fact that distraction is considered one of the underlying mechanisms in the pathophysiology of music therapy.

The exact mechanisms driving the observed reduction in pain scores in group A remain incompletely understood.¹³⁻¹⁴ Contemporary hypotheses suggest that music-induced analgesia arises from a complex interplay between cognitive, emotional, and sensory domains, with music acting simultaneously as a reward, stress reliever, mood regulator, and distractor. These roles collectively influence how individuals cognitively and emotionally regulate pain.^{10, 15}

At the neurophysiological level, music activates the periaqueductal gray (PAG) and the descending pain modulatory system, triggering the release of endogenous opioids like endorphins, which dampen pain signals. It also stimulates the nucleus accumbens (NAc), enhancing dopamine release, which is associated with reward, emotional well-being, and distraction, further modulating pain perception.¹⁶⁻¹⁷ Hormonal mechanisms complement this by reducing cortisol levels-elevated during stress-which amplify pain perception.

Additionally, music downregulates the hypothalamic-pituitary-adrenal (HPA) axis, suppressing corticotropin-releasing hormone (CRH) and adrenaline release, thereby mitigating stress-induced responses like tachycardia and hypertension.¹⁸⁻¹⁹ By recruiting reward and limbic regions and modulating the opioidergic analgesic pathway (PAG-rostral ventromedial medulla-spinal cord), music influences the cognitive, emotional, and physiological dimensions of pain.^{15,20} These mechanisms highlight the multifaceted, non-invasive potential of music as an effective intervention for pain management.

In procedures like arterial puncture, which require a high level of technical skill, the risk of an intervention affecting procedural efficiency is an important consideration. The findings of this study suggest that while acoustic stimulation effectively reduces pain, it does not influence the technical success of arterial puncture. The success of arterial puncture on the first attempt, the proportion of participants requiring multiple attempts, and the distribution of procedure times were comparable between groups, with no statistically significant differences observed. This is consistent with the study conducted in premature infants undergoing blood sampling.⁶ This neutrality in procedural success observed in this study is a critical finding, as it demonstrates that the use of acoustic stimulation does not interfere with the technical aspects of the arterial puncture. This is a significant reassurance for clinicians, as it counters any potential concerns regarding the

possibility of acoustic stimulation distracting healthcare providers or complicating the procedure.

Moreover, the lack of any significant difference in procedure times across the groups further strengthens the argument that acoustic stimulation does not disrupt the clinical workflow. This is an essential point, as maintaining the balance between patient comfort and procedural efficiency is paramount in busy clinical environments. The incorporation of acoustic stimulation into routine practice, as suggested by our findings, appears feasible without increasing the procedure time or decreasing the success rate of the procedure, making it a practical and valuable addition to standard care.

The strength of the present study includes randomized allocation, pragmatic implementation, and clinically relevant outcomes. Limitations include open-label design, single-center setting, and lack of blinding, which may influence subjective pain reports. Music selection was standardized rather than personalized; responsiveness may vary across genres and patient preferences. The study employed only one type of acoustic stimulation, which may not account for the variability in individual responses to different music genres or styles. Moreover, the variability in the skill levels of healthcare providers performing arterial punctures is an inherent confounding factor that could influence both procedural success and pain outcomes. Future research should explore tailored playlists, headset hygiene workflows, and cost-effectiveness.

Implications for nursing practice

Adopt a standardized checklist for offering music therapy during ABG and similar brief invasive procedures (e.g., arterial line removal, venipuncture). Provide disposable headphone covers and maintain infection control. Allow patient input on music selection when feasible. Document intervention use and patient-reported pain to support quality improvement.

CONCLUSION

Music therapy is a simple, low-cost, and nurse-implementable strategy that reduces procedural pain during ABG sampling without affecting procedural success or duration. Incorporation into routine practice can enhance patient experience and aligns with multimodal, opioid-sparing pain management. By adopting such interventions in routine practice, healthcare providers can create a more positive and patient-centered care environment, improving the overall quality of care delivery.

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