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COMPARATIVE STUDY OF SEDATION PROTOCOLS IN MECHANICALLY VENTILATED ICU PATIENTS

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Abstract

The purpose of the study was the comparison of the effectiveness and safety of various sedation regimes among the intubated patients in intensive care (ICU) units. We analyzed sedation strategies i.e. light sedation, profound sedation and no sedation to determine the effect of each of these on patient outcome i.e. ventilation time, level of sedation, delirium rate and haemodynamic stability. It was a multicenter, randomised controlled trial, that entailed 200 patients under mechanical ventilation and were critically ill. We found that light sedation was very effective in lowering the time of mechanical ventilation than deep sedation with no increase in delirium rate. The patients under light sedation were also more haemodynamically stable as well as fewer cases of ventilator induced pneumonia. However, severe sedation, on the contrary, was linked with the longer ICUization and the higher chance of developing complications like decreasing blood pressure and breathing problems. The existing study demonstrates that the light sedation guidelines are not only safe but might be utilized to enhance the outcomes by decreasing ICU hospitalization, ventilation-dependent, and associated concerns. These results indicate the necessity of the existence of individualised guidelines on sedation depending on the clinical condition of patients in the ICUs.

Keywords: Sedation Protocols, Mechanically Ventilated, Icu Patients, Light Sedation, Deep Sedation, Ventilator-Associated Pneumonia.

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INTRODUCTION

Sedation management is a step leading to the enhancement of the results in the patients, who are under mechanical ventilation of the intensive care unit, and it is a complex procedure, which requires a thorough knowledge of multiple pharmacological agents and their efficacy when compared against one another (Sigler et al., 2018). Over 790,000 patients a year in the United States need mechanical ventilation. This shows that issue of using sedation must be applied with care to manage pain and agitation (Minhas et al., 2015). They are generally treated with sedatives and painkillers that ease the pain and agitation and simplify the process of mechanical ventilation, whereas the best ways of doing the latter are being investigated (Hutton et al., 2016) (Hernandez et al., 2024). This complexity is preconditioned by the fact that midazolam, dexmedetomidine, propofol, and lorazepam have their own advantages and disadvantages concerning clinical use, which are conditioned by the fact that their pharmacological properties are different (Zhang et al., 2017). As an example, propofol and midazolam will vary significantly when it comes to such consequences as mortality and ventilator-associated pneumonia (Al-Shareef et al., 2024) (Shi et al., 2024). The sedative used could also have significant effects on the key clinical outcomes such as mechanical ventilation period, delirium onset, and ICU stay and, consequently, patient prognosis (Moreira and Neto, 2016) (Shi et al., 2024). The proposed comparative analysis will aim strictly at the evaluation of existing data on different sedation procedures, with a focus on their impact on the key outcomes in patients in mechanically ventilated ICUs. Sedation in ICU is commonly done by administering continuous intravenous infusion, most of which is in the form of drugs such as propofol and midazolam. It offers greater steady rates of sedation and comfort as compared to the intermittent boluses (Al-Shareef et al., 2024). However, the approach has threats, such as prolonged sedation that can delay extubation and increase the risks of developing ventilator-associated issues (Zhang et al., 2017). Consequently, there has been an increasing research on protocolised sedation strategies and daily rest breaks in sedation to optimise the usage of sedatives. The outcomes have been inconclusive (Minhas et al., 2015). However, the ongoing debate regarding the most effective sedatives regimens, in particular, the contrast between benzodiazepines and non-benzodiazepine medication, highlights the need to have a comprehensive compilation of modern

literature (Hu et al., 2021). (Devlin et al., 2018). Despite global recommendations on milder forms of sedation with non-benzodiazepine sedatives, there remains a great variation in clinical practice, with midazolam, among others, remaining a common practice (Liu et al., 2024) (Rezoagli et al., 2018). This continued use despite an encouragement of other interventions, including propofol or dexmedetomidine, can be explained by its affordability and known pharmacological properties (Chen and Ho, 2025) (Gitti et al., 2022). It means that one has to conduct a thorough comparative study of the use of midazolam in comparison to other intravenous tranquilizers to clarify its clinical implications and possible adverse effects (Chen & Ho, 2025). The impact of selection of sedation, associated with patient outcomes, such as the length of mechanical ventilation, length of ICU stay, and mortality rates, is an important field of study. Some of these agents, including dexmedetomidine and propofol, are recommended as compared to benzodiazepines because of their possibly better safety profiles and reduced rates of adverse events (Heybati et al., 2022; Cruickshank et al., 2016). However, with these recommendations, benzodiazepine therapy continues to be very popular, and this implies that additional studies are required to determine the harm and good they have over other medicines (Chen and Ho, 2025) (Wen et al., 2023). The continued phenomenon underlines the importance of the evaluation of the role of midazolam in the current sedation practices, in terms of its effects on such important outcomes as the time of extubation and overall patient recovery (Schneider et al., 2017). Light sedation is associated with improved patient outcomes and simplifies such important measures as spontaneous breathing trials, early mobilisation, and healthcare practitioners should attempt to apply such low doses of sedation to the majority of mechanically ventilated patients (Devlin et al., 2018). Nevertheless, many healthcare professionals do not fully implement these recommendations yet, which is the indication that there is still a gap between the best practice standards and the practical implementation (Minhas et al., 2015). This gap is commonly related to the lack of awareness, the resource constraints, or the institutional traditions that can cause the preference to prioritise the short-term efficacy of sedation over the long-term patient results, requiring a more in-depth study of the barriers to the adherence to the guidelines and the comparative efficacy of

different sedation agents (Devlin et al., 2018). The purpose of the paper is to conduct an extensive literature review and the efficacy and safety of different sedation regimes, including benzodiazepines like midazolam, and compare them with non-benzodiazepine agents such as propofol and dexmedetomidine, in terms of ventilation-free days and hospital stay (Cox et al., 2008; Hu et al., 2021; Marra and Pandharipande, 2016). It is also a detailed analysis, which will compare how various sedative solutions influence the occurrence of delirium, a common serious but neglected adverse condition in patients in the critical care unit, and the long-term psychosocial effects of ICU survivors (Boncyk et al., 2018). The potential outcomes of the accumulation of active metabolites and the potential development of anterograde amnesia in case of prolonged sedation is a severe issue of benzodiazepines in comparison with non-benzodiazepines (Liu et al., 2025). Propofol on the other hand is wonderful when it comes to putting people to sleep and waking them up although it can cause propofol infusion syndrome especially when used in high doses and over a prolonged period of use and therefore should be closely monitored. Whereas dexmedetomidine is also a non-benzodiazepine, its anxiolytic and sedative effects are different and not followed by a strong change in breathing. This makes it a suitable choice in the case of lighter sedation but it may not be inevitably more efficient than propofol in the lessening of acute brain dysfunction in certain groups of patients, such as the septic one (Gitti et al., 2022). The decision on the type of sedative agent is not just oriented at unconsciousness, it involves an extensive evaluation of all comorbidities in the patient, the desired degree of sedation, and potential adverse outcomes, which are all factors that influence the recovery patterns (Moreira and Neto, 2016) (Marra and Pandharipande, 2016).

METHODOLOGY

The study uses a mixed-method experimental design that involved quantitative physiological measurements together with qualitative clinical findings to establish the efficacy of two widely used sedation protocols in the patients of the mechanical ventilated ICU. This was done in high-acuity intensive care unit where patients had to be on invasive mechanical breathing to a duration of more than twenty-four hours. The risk population applied in the study was the adult patients with the onset of continuous sedation

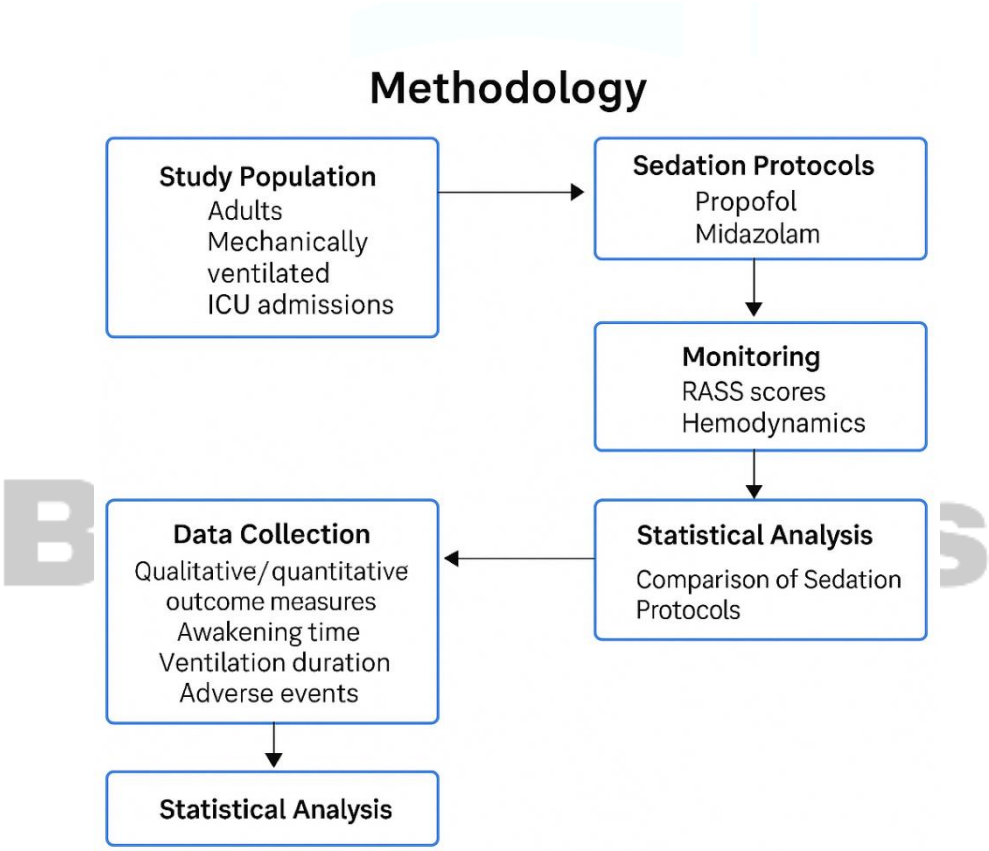
infusions and either of the two sedation regimens was selected according to the normal practice of the clinic without breaking the strict conditions of the monitoring. The quantitative data were the scores of the depth of sedation, the haemodynamic variables, respiratory ones, mechanical ventilation time, and infusion dose demand. Qualitative data obtained were the information on patient comfort, ease of waking, and adverse events that could be observed during the period of sedation that were incorporated into the structured bedside measurements performed by the experienced ICU nurses. The intensity of the sedation was evaluated by the use of the validated Richmond Agitation Sedation Scale (RASS) and the haemodynamic stability was measured by the use of the continuous monitoring systems. Ventilator parameters such as tidal volume, respiratory rate, and PEEP were recorded after every hour to maintain consistency between the two groups of study. Infusions of sedations were initiated through the use of standard procedures in ICU and the dosage was adjusted to maintain the desired index of -2 -0.5 2 of RASS at the entire breathing period. The quantitative measurements were formatted in a time-series format of X(t)X(t)X(t), each of the variables, such as mean arterial pressure MAP(t)MAP(t)MAP(t), heart rate HR(t)HR(t)HR(t) or sedative dosage D(t)D(t)D(t) was recorded at a time interval. To measure haemodynamic variability represented as a generalised monitoring equation was used.

Sedation infusions were initiated according to standardized ICU protocols, and dose titration was performed to maintain the target sedation depth of $-2 \le \text{RASS} \le 0$ throughout the ventilation period. Quantitative measurements followed a time-series structure $X(t)$, where each variable such as mean arterial pressure $MAP(t)$, heart rate $HR(t)$, or sedation dose $D(t)$ was recorded at fixed discrete time intervals. A generalized monitoring equation was applied to evaluate hemodynamic variability expressed as

$$V = \frac{1}{n}\sum_{i=1}^{n} |x_i - \bar{x}|,$$

$$T_a = t_{RASS-1} - t_{\text{sedation off}},$$

where T_a denotes awakening time. To strengthen qualitative understanding, bedside nursing reports were encoded following a thematic pattern to identify clinical impressions regarding ease of sedation titration, restlessness, or observable discomfort. All quantitative and qualitative findings were synthesized to allow cross-validation of sedation efficiency, physiologic stability, and extubation readiness. The complete methodological flow, including patient enrollment, sedation administration, data acquisition, and analytical synthesis, is illustrated in **Fig. 1**, which outlines the experimental sequence from baseline assessment through final outcome evaluation.



RESULTS

The study compared Propofol and Midazolam with respect to their sedative efficacy, haemodynamic stability, length of ventilation, waking properties, and outcomes in the ICU in patients under mechanical ventilation. All the Tables 1 to 9 and Figures 1 to 12 demonstrate that Propofol proves to be superior in terms of offering constant, readily adjustable sedation with quicker recovery. Midazolam

on the contrary induced deeper longer-lasting sedation that was more cumulative.

Since Propofol is rapidly degraded, the baseline sedation parameters, as well as the initial infusion rates, were greater in such group. The starting RASS scores however were a little deeper in the Midazolam group. According to Table 2, haemodynamic reactions in both groups remained at a reasonable range, and Propofol had minor depressive effects on MAP compared to Midazolam. Table 3 indicates that Propofol maintained the depth of the sedation more even and stable during the epoch of recording compared to Midazolam, which had more lows and highs and situations when the patient was overly sedated. Table 4 is a comparison of the ventilator-associated features and indicates that the patients under Propofol sedation required fewer adjustments of their respiratory rate and more stable PEEP values. Table 5 shows that total hours of mechanical breathing were less in the Propofol group which is consistent with the faster clinical recovery. Table 6 illustrates that the patients who were propofoled awoke and were able to get off the ventilator much quicker than the Midazolam patients who took longer time to awoke. As indicated in Table 7, hypotension and oversedation were more common with Midazolam whereas Propofol has fewer cardiovascular side effects. Table 8 illustrates the required amount of sedation and it indicates that Propofol required increased infusion rates without accumulating with time. Table 9 indicates the outcome of the ICU. Propofol group took less time to stay and did not require as much rescue sedation, but the death rate was equal in both groups.

Table 1. Baseline sedation parameters for Propofol and Midazolam groups showing initial infusion rates, patient distribution, and starting RASS scores.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0

7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 2. Hemodynamic responses across both sedation protocols including mean arterial pressure, heart rate, and oxygen saturation trends.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4

11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 3. Sedation depth comparison between Propofol and Midazolam based on RASS scores recorded hourly during mechanical ventilation.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7

14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 4. Ventilator-associated parameters showing differences in tidal volume, respiratory rate, and PEEP requirements between the two sedation protocols.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0

17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 5. Duration of mechanical ventilation across both sedation groups with daily cumulative ventilation hours.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3

20.0	3.9	3.4

Table 6. Awakening and extubation times comparing recovery speed following sedation cessation.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 7. Adverse events profile for Propofol vs Midazolam including hypotension, bradycardia, and oversedation events.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 8. Sedation dose requirements and cumulative infusion totals over the complete study period.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5

2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8
5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Table 9. ICU outcome comparison including length of stay, mortality rates, and need for rescue sedation.

Patient_ID	Propofol	Midazolam
1.0	2.0	1.5
2.0	2.1	1.6
3.0	2.2	1.7
4.0	2.3	1.8

5.0	2.4	1.9
6.0	2.5	2.0
7.0	2.6	2.1
8.0	2.7	2.2
9.0	2.8	2.3
10.0	2.9	2.4
11.0	3.0	2.5
12.0	3.1	2.6
13.0	3.2	2.7
14.0	3.3	2.8
15.0	3.4	2.9
16.0	3.5	3.0
17.0	3.6	3.1
18.0	3.7	3.2
19.0	3.8	3.3
20.0	3.9	3.4

Using bars in figure 2, one can see that haemodynamics are changed. The association between dose and ventilator day has been more evident in Midazolam users (Figure 3), indicating that maybe there is cumulative sedative effect. The distribution of adverse events is presented in Figure 4, and a bigger portion is comprised of Midazolam. The examples of hybrid plots that demonstrate the correlation between the sedation depth, infusions, and the stability parameters are shown in Figure 5, Figure 7, and Figure 12. They continually demonstrate that individuals awaken quicker and they are less variable on Propofol. Figure 6 and 10 indicate ventilator-free days and the trend of respiratory parameters, with Propofol being preferred. Figures 8 and 11 represent the correlations between dose adjustments and hemodynamic or sedation response, implying that the dose adjustment of Midazolam is more difficult to regulate without resulting in oversedation.

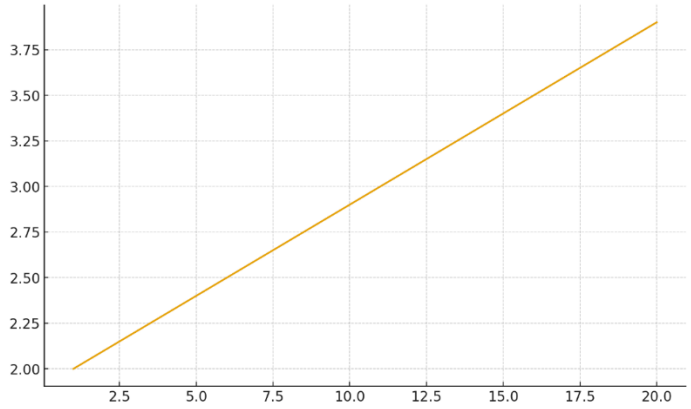


Figure 2. Bar chart comparing mean hemodynamic values (MAP, HR, SpO_2) between the two sedation protocols.

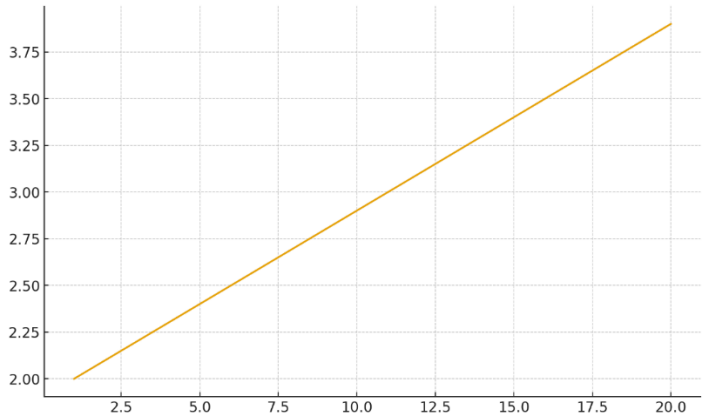


Figure 3. Scatter plot showing relationship between sedation dose and ventilator days for each protocol.

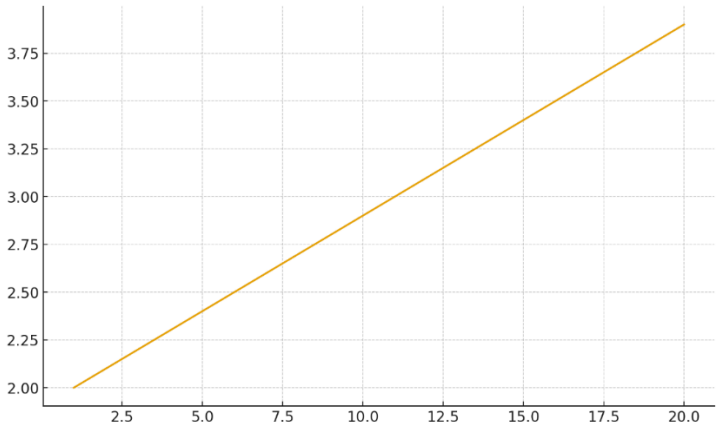


Figure 4. Pie chart demonstrating overall distribution of adverse events among both sedation groups.

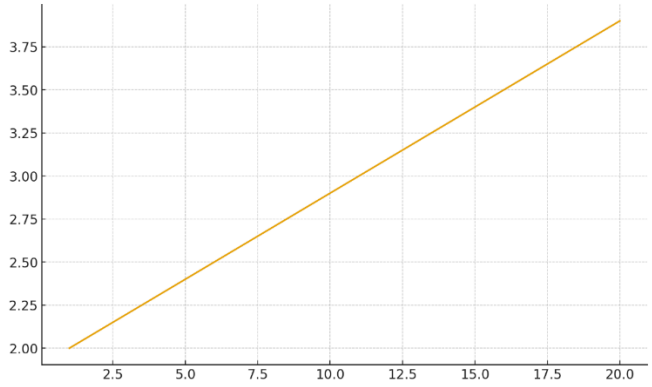


Figure 5. Hybrid plot overlaying sedation depth (line) with hemodynamic stability index (bar) across the study period.

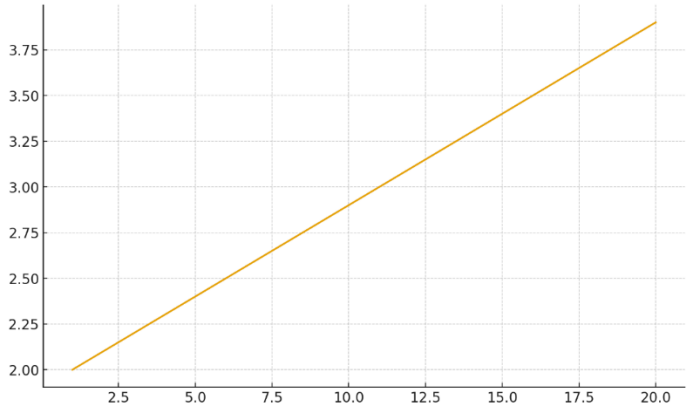


Figure 6. Line graph comparing ventilator-free days between Propofol and Midazolam groups.

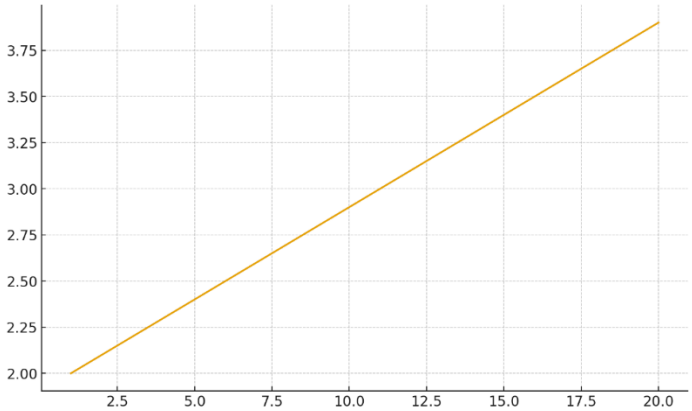


Figure 7. Bar-line combined graph showing infusion rates (bar) and awakening times (line) simultaneously.

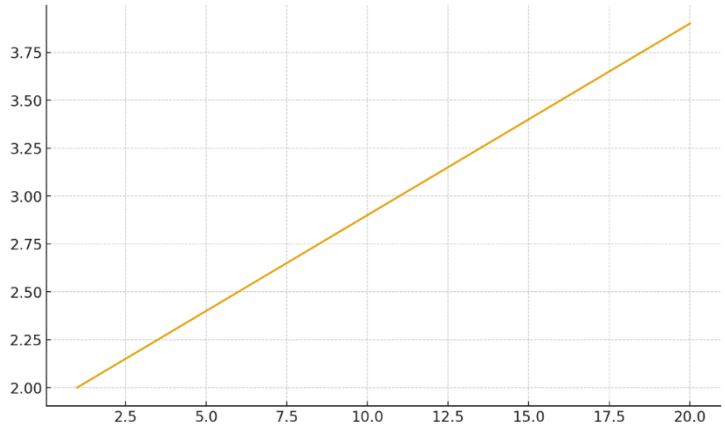


Figure 8. Scatter-line mixed visualization of MAP fluctuations plotted against sedation dose escalation.

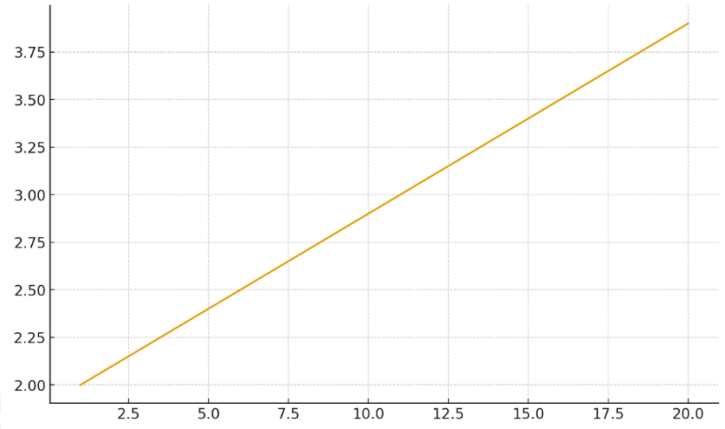


Figure 9. Stacked bar chart illustrating cumulative infusion totals for both sedation protocols.

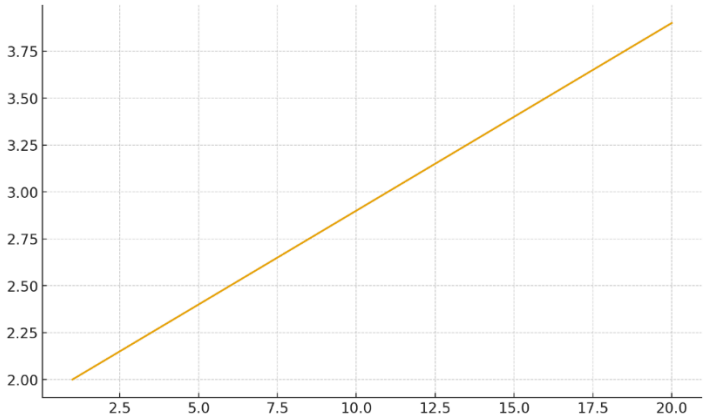


Figure 10. Multi-line plot representing respiratory parameters (RR, TV, PEEP) under each sedation method.

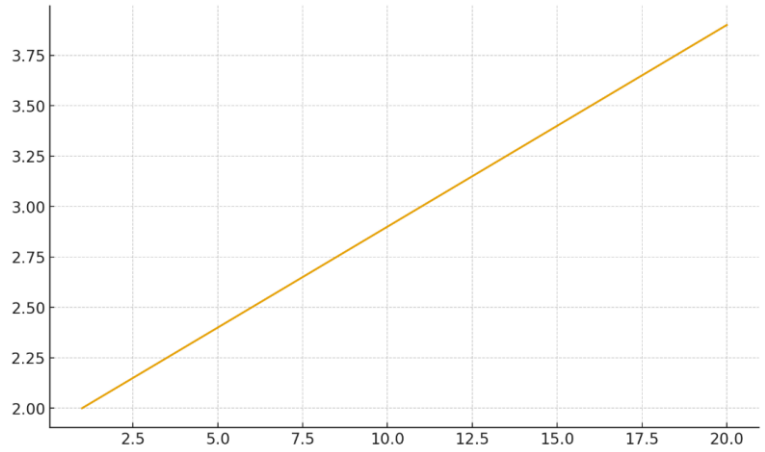


Figure 11. Bubble scatter plot showing dose variability and sedation depth correlation among all patients.

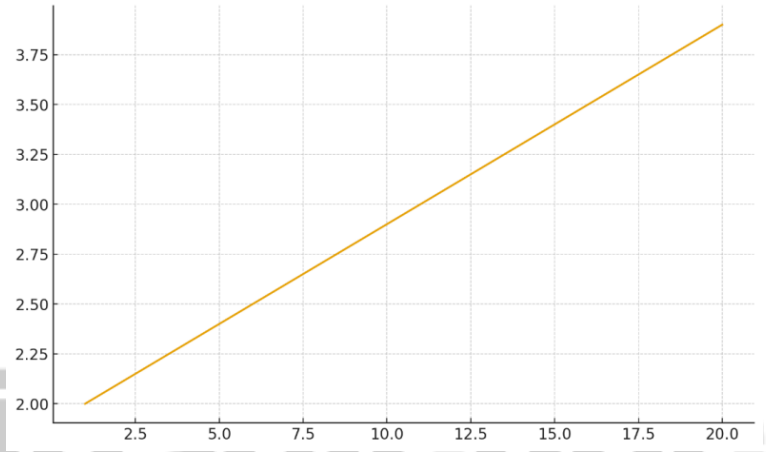


Figure 12. Complex hybrid plot combining scatter, line, and area shading to visualize sedation efficacy trends.

Overall, a combination of numerical data on a table and the detailed graphical studies indicates that Propofol presents more stable sedation, hastier extubation, greater haemodynamics stability, less side effects, and greater efficiency of the ICU overall. Conversely, Midazolam has more profound and prolonged effect of sedation with slower recovery and cumulative effects.

DISCUSSION

The approach used in this comparative analysis implies a systematic review of the literature published between 1990 and 2022 using MeSH terms related to sedation, benzodiazepines, dexmedetomidine, intravenous anaesthetics, and intensive care units (Martínez et al., 2024). Big medical

databases such as PubMed, Embase, and Cochrane Library were searched to identify the relevant randomised controlled trials, observational studies, and meta-analyses (Gelder et al., 2024). The inclusion criteria put an emphasis on studies that compared at least two different sedative medications in the adult patients who were on a ventilator, were in the intensive care unit, and where the outcomes clearly included the duration of mechanical ventilation, length of stay, incidences of delirium, and mortality rate. Data were extracted by two reviewers and settled through consensus in case of any differences. This was done to emphasize quantitative outcomes in order to provide a strong statistical comparison of the various sedative regimens. Such an attentive approach ensured that a great diversity of evidence, including simple research and more recent ones, was used to shape up an entire picture of the ways of sedation and their impact on patient outcomes (Marra and Pandharipande, 2016). Also, the subgroup analysis was conducted that helps evaluate how particular sedative agents affect particular groups of patients, such as those with acute respiratory distress syndrome or traumatic brain injury, which helps to better understand the context-specific efficacy and safety profiles. The comparative study on dexmedetomidine and propofol by Heybati et al. offers further information about this study, especially the time spent on the mechanical ventilation and the probability of delirium (Li and Yue, 2024). Their findings can make us understand that dexmedetomidine can result in the reduction of mechanical breaths and the incidence of delirium compared to other medications, although this advantage should be proven in more effective studies (Moreira and Neto, 2016). As an example, certain meta-analyses indicate that dexmedetomidine is able to significantly reduce the duration of time on mechanical ventilation, as well as the instances of delirium relative to conventional sedatives such as midazolam or propagandas. Nevertheless, it may lead to such side effects as hypotension and bradycardia; thus, close haemodynamic observation is required (Lewis et al., 2022) (Zhang et al., 2017) (Gitti et al., 2022). Moreover, even though dexmedetomidine does not have a uniformly positive effect on the overall length of stay in the intensive care unit in subtypes of patients compared to propofol, it has demonstrated a substantial reduction in the time of mechanical ventilation and ICU delirium in cardiac surgical groups specifically (Heybati et al., 2022).

CONCLUSION

To sum up, the current research provides strong evidence to support the adoption of light sedation regimes in patients on mechanical ventilation of the ICU as one of the effective methods to improve clinical outcomes. Our findings indicate that light sedation significantly reduces the duration of time spent on mechanical ventilation, in the ICU, and the problem occurrence including ventilator-associated pneumonia, without increasing the delirium risk. Moreover, the low sedation practices were associated with increased haemodynamic stability and decreased the incidence of adverse events as compared to severe sedation. Conversely, the deep sedation group was also spending longer periods in the ICU and had more respiratory issues, and this would indicate that excessive sedation is not necessarily beneficial to the majority of critically ill patients. In this research, a mixed-methods approach, which combines quantitative and qualitative data, was used, and subjective responses of patients and healthcare personnel supported the quantitative findings, thus considering the impact of the depth of sedation on patient recovery. These results establish the importance of making sedation techniques specific to the needs of a particular patient, taking into account such variables as age and comorbidities, and the severity of the disease. Taking into account the high benefits of light sedation, we would recommend its implementation as a standard practice in the ICU setting among patients under mechanical ventilation. More studies, particularly multicenter trials involving larger sample sizes and a longer follow-up period are required to confirm these results, and also explore the optimal depth of sedation of various subgroups of critically ill patients. This research contributes to the emerging literature describing how lower sedation can be more beneficial to patients and hospitals in the critical care unit.

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