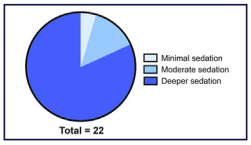

Ketamine/Midazolam versus Fentanyl/Midazolam Sedation for Interventional Radiology Procedures: A Prospective Registry

Gaspareantonio Fabio Greco, BS, Zayd Al-Asadi, BS, Adam M. Belcher, PhD, Elaine Mattox, EdD, Michael V. Korona, MD, and Amy R. Deipolyi, MD, PhD

ABSTRACT

Purpose: To assess whether sedation with ketamine/midazolam was more effective than fentanyl/midazolam at reducing periprocedural pain scores for interventional radiology (IR) procedures.

Materials and Methods: Data on preprocedural, intraprocedural, and postprocedural pain scores, procedure duration, and moderate or worse adverse events (AEs) were collected as part of a prospective quality improvement registry before and after the introduction of a ketamine/midazolam sedation program at a single academic center, including 292 procedures performed on adult patients from April 2024 to August 2024. All IR staff were surveyed before and after the introduction of ketamine regarding their observations on sedation, with 23 respondents at baseline survey and 22 at follow-up.

Results: Compared with fentanyl/midazolam sedation, ketamine/midazolam sedation was associated with lower intraprocedural ($P \leq .001$) and postprocedural ($P \leq .05$) pain scores, without prolonging procedure duration ($P = .436$) or increasing AEs ($P > .999$). The effect on pain scores was observed for biopsy and drainage, but not for venous port procedures. Staff reported that ketamine/midazolam sedation provided adequate comfort more often than fentanyl/midazolam sedation ($P \leq .01$), and at study conclusion, most (82%) reported that they would choose ketamine/midazolam sedation for themselves.

Conclusions: Compared with fentanyl/midazolam, ketamine/midazolam sedation was superior regarding reduction of patient discomfort and preference by IR staff, with no added procedural duration or AEs when administered in the absence of anesthesiology providers. Findings suggest further investigation into incorporating ketamine into routine use in IR programs.

ABBREVIATIONS

IR = interventional radiology, IRB = institutional review board

Interventional radiology (IR) involves high volumes of brief procedures that can cause acute discomfort. To manage patient distress and to enable cooperation, interventional radiologists usually administer moderate sedation (1) with a combination of an opioid (fentanyl) and benzodiazepine (midazolam) (2). Approximately 20% of patients do not tolerate or find this regimen inadequate (3,4). There is increasing public awareness of patient-centered experience and concern for pain during invasive procedures (5). While other medical specialties, like gastroenterology, have transitioned away from moderate sedation to deep sedation or monitored anesthesia care (6,7), moderate sedation continues as the primary sedation strategy in IR. An ideal regimen would provide deeper sedation without impairing respiration, enabling interventional radiologists to deliver better patient-centered experiences without increasing demands on progressively understaffed anesthesiology groups (8,9).

Ketamine, a dissociative/hypnotic anesthetic, is uniquely suited for nonanesthesiology providers to sedate patients while performing procedures. Unlike other sedatives, ketamine does not reduce blood pressure or depress respiratory function (10). Ketamine reduces postprocedural pain and opioid consumption (11,12). Ketamine has had a resurgence and is now used to treat chronic pain and depression (13). Ketamine sedation is the preferred approach by emergency department physicians during painful procedures, per their societal guidelines (14). Data regarding the safety and

Figure E1 can be found by accessing the online version of this article on *www.jvir.org* and selecting the Supplemental Material tab.

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RESEARCH HIGHLIGHTS

- Ketamine/midazolam sedation resulted in significantly decreased intraprocedural and postprocedural pain scores compared with fentanyl/midazolam sedation.
- Pain score reduction was evident for biopsy and drainage procedures but not venous port procedures.
- Ketamine/midazolam and fentanyl/midazolam sedation cases did not differ in procedure length or adverse events.
- Staff reported that deep sedation with ketamine was superior to moderate sedation in providing patient comfort during procedures and endorsed that they would choose deep sedation for themselves.
- Ketamine/midazolam sedation was safe and effective when administered by interventional radiologists independent of anesthesia providers.

STUDY DETAILS

Study type: Prospective, observational, cohort study

Level of evidence: 3 (SIR-C)

effectiveness of ketamine is required to justify IR societal guidelines incorporating it into sedation protocols.

This prospective registry study documented the outcomes of all procedures performed with fentanyl, midazolam, and/or ketamine at a single institution before and after the initiation of a ketamine sedation program. The purpose was to evaluate the effectiveness and safety of ketamine/midazolam sedation compared with fentanyl/midazolam sedation. All IR staff were surveyed before and after introducing ketamine sedation regarding their observations on sedation. The hypothesis was that ketamine/midazolam sedation would provide superior pain control during and after IR procedures.

MATERIALS AND METHODS

Prospective IR Quality Improvement Registry

This Charleston Area Medical Center institutional review board (IRB)-approved, Health Insurance Portability and Accountability Act (HIPAA)-compliant project involved collecting data in a prospective IR quality improvement registry (IRB protocols: 23-935 and 24-1066). The registry's purpose was to collect uniform clinical data regarding patient-reported outcomes for all patients undergoing IR procedures, generating a database to evaluate the clinical effectiveness and safety of ketamine/midazolam sedation administered by interventional radiologists (15). All 292 consecutive procedures performed on adult patients (≥18 years) by 2 board-certified interventional radiologists (A.D., M.K.) with 10 and 21 years of experience at a single institution using fentanyl, midazolam, and/or ketamine, from April 1, 2024, to August 19, 2024, were included (Table 1). Before the introduction of ketamine in late May, 2024, fentanyl/midazolam sedation was used for procedures whenever possible; single-agent sedation with either fentanyl or midazolam was used if the patient had not fasted or had another contraindication to sedation with 2 agents. Contraindications to fentanyl/midazolam sedation included hypotension (systolic blood pressure < 90 mm Hg), respiratory failure, or allergy to opiates or benzodiazepines. After introducing ketamine, ketamine/midazolam sedation was used whenever possible. Contraindications to ketamine/midazolam sedation included uncontrolled hypertension, a condition for which hypertension is a concern (eg, aortic dissection), allergy to ketamine or midazolam, and schizophrenia. At Charleston Area Medical Center, 2 nurses were required to monitor patients when ketamine was used.

Table 1. Summary of Cases in Prospective Registry

Characteristic	Fentanyl/midazolam sedation	Ketamine/midazolam sedation	*P*
Number of patients (n)	183	89	
Age	65 ± 12	63 ± 15	.201
Self-reported gender			
Women	83 (45)	45 (51)	.440
Men	100 (55)	44 (49)	
Visit type			
Inpatient	74 (40)	40 (45)	.531
Outpatient	109 (60)	49 (55)	
Procedure			**.017**
Biopsy	95 (52)	37 (42)	
Bone/bone marrow	34	5	
Lung	23	11	
Liver	15	8	
Retroperitoneal	8	3	
Spine	4	3	
Other	11	7	
Drainage procedure	45 (25)	34 (38)	
Chest tube placement	5	5	
Abscess drain placement	28	15	
Drain exchange	5	6	
Gastrostomy tube placement	3	2	
GU tube placement	4	6	
Venous port placement/removal	23 (13)	15 (17)	
Other	20 (11)	3 (3)	
Comorbidities			
Obesity (BMI ≥ 30)	64 (35)	29 (33)	
Sleep apnea	30 (16)	14 (16)	
Opiate use/abuse	8 (4)	2 (2)	
Baseline variables			
BMI (kg/m^2)	29 ± 9	29 ± 9	.522
SBP (mm Hg)	135 ± 20	134 ± 22	.850
Oxygen saturation (%)	98 ± 2	98 ± 2	.513

Note–Data are presented as mean ± SD or number (percentage of the sedation group). More of the ketamine/midazolam procedures involved drainages.
BMI = body mass index; GU = genitourinary; SBP = systolic blood pressure.

The fentanyl/midazolam or ketamine/midazolam sedation groups were similar, although more of the ketamine/midazolam procedures involved drainages (Table 1).

The interventional radiologists had extensive previous experience with fentanyl/midazolam sedation and were Advanced Cardiac Life Support-certified. Deep sedation privileges were requested from the hospital's sedation committee. The interventional radiologists were proctored by anesthesiology and emergency medicine physicians, who observed 3 ketamine sedation cases, 1 insertion of an oral or nasal airway, and 1 bag-valve-mask ventilation and provided verbal instruction regarding anticipated adverse events (AEs) like emergence reactions prevented and treated with midazolam.

During the study period, 20 cases were performed with 1 agent (15: midazolam; 5: fentanyl). There were 6 procedures performed with ketamine/midazolam under proctoring in the first month of the study period. Deep sedation privileges were granted at the end of the second month. By that time, 179 cases had been performed with fentanyl/midazolam as the default. Starting in June, there were 4 additional cases performed with fentanyl/midazolam, due to only 1 nurse being available, for a total 183 cases performed with fentanyl/midazolam. Eighty-three cases were performed starting in the third month with ketamine/midazolam, for a total of 89 cases performed with ketamine/midazolam.

Prospective nonrandomized data were collected on a standardized data collection sheet by the IR procedure nurse (Fig E1, available online on the article's Supplemental Material page at *www.jvir.org*). Patient demographics were documented. The IR nurse noted the maximum Numeric Rating Score pain score (16) immediately before, during, and after the procedure, using a scale from 0 (no pain) to 10 (worst possible pain). Intraprocedure maximal pain score was solicited just after the procedure had ended, once the patients were able to communicate verbally. Patients who had no memory of the procedure were scored as 0 for the maximum intraprocedural pain score. Postprocedural maximal pain score was assessed just before leaving the procedure room. The performing physician, procedure type, amounts of sedative medications, and any intraprocedural moderate or worse AEs by the Society of Interventional Radiology (SIR) Adverse Event Classification (17) were noted.

Study investigators later conducted a retrospective chart review to record patients' height, weight, and history of sleep apnea or opioid use/abuse. Body mass index was calculated from the height and weight. Procedural documentation was reviewed to record the Aldrete scores (18) observed by the procedural nurse, if any pain medications were administered in the postprocedural recovery area, or if any AEs occurred later. Aldrete scores were documented just before administering sedatives and just before the patient departed the procedure room per hospital protocol. Additionally, the baseline, highest, and lowest systolic blood pressure; the baseline and lowest oxygen saturation; and the amount and method of supplemental oxygen administered were recorded from procedural documentation. Charts were reviewed to identify the standard of care postprocedural IR nurse phone call made to patients 1–3 days after procedures. Patients were asked whether (*a*) they were satisfied with the level of sedation and (*b*) whether they would want more, less, or the same amount of sedation if the procedure were repeated. Only 3 patients of the single-agent sedation group, 57 of the fentanyl/midazolam group, and 19 of the ketamine/midazolam group were able to be contacted.

Sedation Protocols

Single-agent sedation involved either fentanyl or midazolam at the interventional radiologists' discretion. Fentanyl/midazolam sedation involved intravenous administration of midazolam and fentanyl, using a loading dose of 0.5–1 mg midazolam and 25–50 μg of fentanyl, with 0.5 mg midazolam and 25 μg boluses as needed. Once deep sedation privileges had been granted, ketamine/midazolam was used whenever possible to minimize bias. Ketamine/midazolam sedation was administered intravenously by giving a 1–2 mg midazolam bolus initially, with a 30-mg ketamine bolus 3–5 minutes later. Additional 10–20 mg ketamine and 0.5–1 mg midazolam boluses were given as needed, with a maximum total dose of 100 mg ketamine and 5 mg midazolam. Owing to state nursing board regulations, IR procedure nurses administered midazolam and fentanyl, but only interventional radiologists administered ketamine.

For single-agent sedation, median dose of midazolam was 1 mg (range, 0.5–2 mg) and of fentanyl was 50 μg (range, 25–150 μg). Two (10%) patients also received 25 mg diphenhydramine during the procedure. Fentanyl/midazolam sedation was administered at a median dose of 1 mg (range, 0.5–3 mg) midazolam and 50 μg (range, 25–150μg) fentanyl, with 32 of the 184 (17%) receiving diphenhydramine at a median dose of 25 mg (range, 25–50 mg). Ketamine/midazolam sedation was administered with a median dose of 2 mg (range, 0.5–3 mg) midazolam and 30 mg (range, 30–50 mg) ketamine. No patients who received ketamine/midazolam sedation received diphenhydramine. Mean ketamine dose administered was 0.42 mg/kg (SD ± 0.13; range, 0.16–0.80 mg/kg).

Staff Surveys

IRB-approved staff surveys were conducted 6 weeks before the initiation of the ketamine sedation program and 6 weeks after ketamine sedation was introduced. The surveys were developed by the study principal investigator. Owing to the paucity of validated tools to assess health care providers' perceptions of procedural sedation, the content of the questions was based on previous survey studies (19,20). All responses were anonymous. Each survey asked what the role of the team member was (physician, nurse, technologist, or advanced practitioner) and what they considered was the maximum acceptable pain score for a patient during

Table 2. Number of Respondents to Staff Survey by Team Role

Team role	Initial	Follow-up
Nurse	11	10
Doctor	2	2
Technologist	8	8
Advanced practitioner	2	2

a procedure. The baseline survey asked the following questions: (*a*) How well do you think that moderate sedation provides adequate comfort to patients? (*b*) How often do you feel uncomfortable that patients are in too much distress during IR procedures with moderate sedation? (*c*) How often do patients experience side effects from moderate sedation during IR procedures; (*d*) If you could change the average level of sedation for IR procedures, how would you change it? The follow-up survey asked the following questions: (*a*) How well do you think that deeper sedation provided adequate comfort to patients? (*b*) How often did you feel uncomfortable that patients were in too much distress during IR procedures with deeper sedation? (*c*) How often did patients experience side effects from deeper sedation during IR procedures? (*d*) If you had to have a painful procedure performed in IR such as an abscess drainage, which type of sedation would you prefer (local anesthesia only, minimal sedation with 1 agent, moderate sedation with fentanyl and midazolam, or deeper sedation with ketamine and midazolam)?

There were 23 respondents to the initial survey and 22 respondents in the follow-up survey after introduction of the ketamine sedation program, with a similar distribution by team member role (Table 2). Similar numbers of nurses, doctors, technologists, and advanced practitioners responded to the staff surveys administered at baseline and follow-up ($P > .999$).

Statistical Analysis

Statistical analysis was performed with Prism (v10.3.1; GraphPad, Boston, Massachusetts), with an α level of $P < .05$. Sedation groups were compared using an unpaired *t* tests and Mann–Whitney *U* tests for normal and nonparametric data and with Fisher exact tests for categorical data. Because so few of the procedure end times were documented on the data collection tool, procedure duration was calculated from the time between the preprocedural and postprocedural Aldrete scores. Patients were categorized as satisfied or not satisfied based on the nurse's postprocedural phone call; groups were compared by sedation type with Fisher exact tests. Staff survey responses were compared with unpaired *t* tests.

RESULTS

Prospective Registry

When considering all procedure types together, ketamine/midazolam sedation resulted in significantly lower mean maximum pain scores during ($P \leq .0001$) and after ($P \leq .05$) procedures, compared with fentanyl/midazolam sedation (Fig 1a). Pain scores were not significantly different before sedation administration ($P > .05$). Single-agent and fentanyl/midazolam sedation were not significantly different in terms of pain scores during and after the procedure ($P > .05$), although the number of single-agent sedation cases was low. When considering pain scores by procedure type, compared with fentanyl/midazolam sedation, ketamine/midazolam sedation was associated with lower intraprocedural pain scores for biopsy ($P \leq .001$) and lower intraprocedural ($P \leq .001$) and postprocedural ($P \leq .01$) pain scores for drainage procedures, but not venous port cases ($P > .05$) (Fig 1b). There were too few drainage and venous port cases performed with single-agent sedation to include it for analysis.

Procedures performed with fentanyl/midazolam sedation lasted a mean of 2 minutes longer than those performed with ketamine/midazolam sedation, although the difference was not significant ($P > .05$) (Fig 2a). Procedure durations were not significantly different between sedation groups, when considering biopsies, drainages, and venous access cases separately (Fig 2b). Median postprocedural Aldrete scores were 10 for the fentanyl/midazolam group (range, 7−10) and 10 for the ketamine/midazolam group (range, 9−10; $P = .534$).

Only 7 (2%) of the 292 cases were pain medications administered in the postprocedural space, including 1 (5%) of the 20 single-agent sedation, 2 (1%) of the 183 moderate sedation, and 4 (4%) of the 89 ketamine sedation cases ($P = .131$). Antinausea medications were administered during or immediately after 6 (2%) of the 292 procedures, including 1 (5%) of the 20 single-agent sedation, 3 (2%) of the 183 moderate sedation, and 2 (2%) of the 89 ketamine sedation cases ($P = .369$).

Highest intraprocedure systolic blood pressure was a mean of 137 mm Hg (SD ± 20) for the fentanyl/midazolam group and 143 mm Hg (SD ± 20) for the ketamine/midazolam group ($P = .015$). There were 2 patients (1%) in the fentanyl/midazolam group who had systolic blood pressure >200 mm Hg during the procedure, compared with no patients in the other sedation groups ($P > .999$). Lowest systolic blood pressure was a mean of 122 mm Hg (SD ± 19) for the fentanyl/midazolam group and 124 mm Hg (SD ± 21) for the ketamine/midazolam group ($P = .333$). There were 4 patients (2%) in the fentanyl/midazolam group who had systolic blood pressure <90 mm Hg during the procedure, compared with 2 patients (2%) in the ketamine/midazolam group and none in the single-agent group ($P > .999$).

Lowest oxygen saturation was a mean of 96% (SD ± 3%) for the fentanyl/midazolam group and 96% (SD ± 3%) for the ketamine/midazolam group ($P = 0.462$). No patients in the single-agent, 4 in the fentanyl/midazolam (2%), and 2 in the ketamine/midazolam (2%) groups received supplemental oxygen through a device more invasive than a standard nasal cannula or room air ($P > .999$). In the fentanyl/midazolam group, 1 patient was given a nonrebreather mask, 1 patient continuous positive airway pressure, 1 patient a tracheostomy mask, and 1 patient a high flow nasal cannula. In the

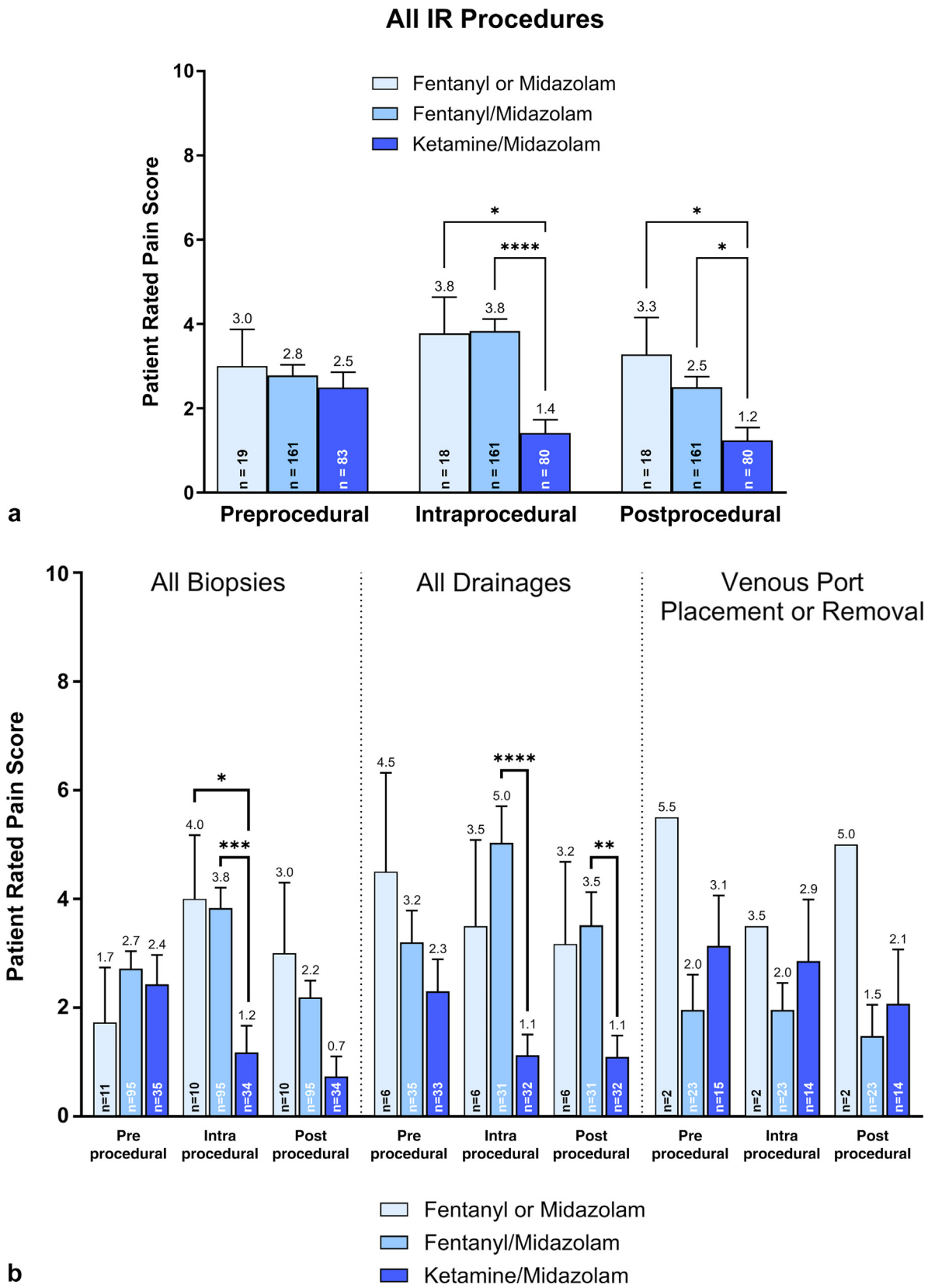

Figure 1. Pain scores before, during, and after procedures by sedation group. **(a)** When assessing all procedures combined by sedation type, ketamine/midazolam sedation was associated with decreased maximum pain scores during and after the procedure compared with single-agent and fentanyl/midazolam sedation. **(b)** When considering procedure types separately, ketamine/midazolam sedation resulted in reduced maximum pain scores during biopsies, and during and after drainages, but not venous port placement and removal. *$P \leq .05$; **$P \leq .01$; ***$P \leq .001$; ****$P \leq .0001$. Error bars are standard errors of the mean. IR = interventional radiology.

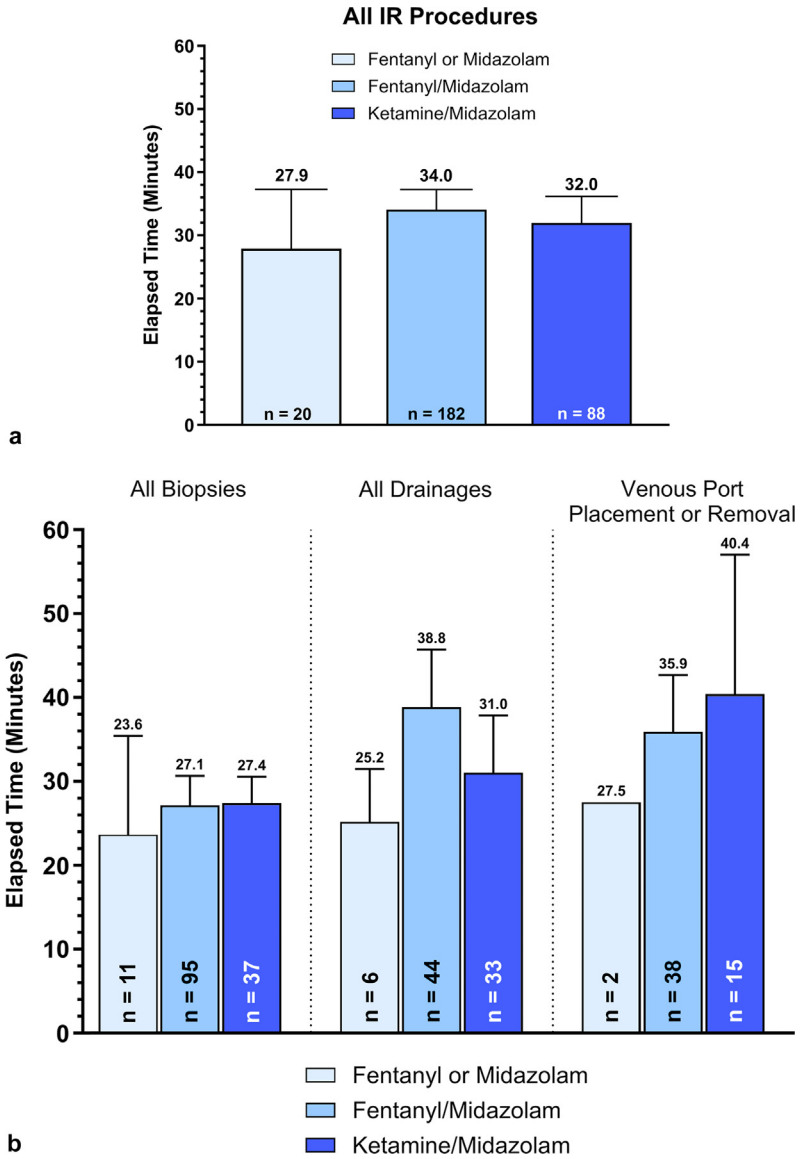

Figure 2. Procedure durations. There was no significant difference in procedure duration by sedation type when **(a)** considering all procedures together or **(b)** separately by procedure type ($P > .05$). Error bars are 95% CIs. IR = interventional radiology.

ketamine/midazolam group, 1 patient was given a non-rebreather mask and the other a tracheostomy mask.

Moderate or worse AEs were rare, occurring in 3 (1%) of the 292 cases. There were no AEs observed after minimal sedation cases; there were 2 AEs after fentanyl/midazolam sedation (including 1 pneumothorax requiring chest tube placement and 1 rapid response call for suspected oversedation prompting administration of reversal agents); there was 1 pneumothorax requiring chest tube placement after ketamine/midazolam sedation ($P > .999$). Among the 292 cases, there were no incidents requiring escalation of care to the intensive care unit or hospitalization, endotracheal intubation, need for positive pressure ventilation, or oral airway insertion.

Most patients who were reached for standard of care postprocedural phone calls endorsed satisfaction with the level of sedation given for their procedure (Fig 3). One (33%) of the 3 patients in the single-agent, 5 (9%) of the 57 in the fentanyl/midazolam, and 3 (16%) of the 19 in the ketamine/midazolam sedation groups endorsed that they would prefer a deeper level of sedation if they had to repeat the procedure ($P = .214$). One patient in the fentanyl/midazolam sedation group and 2 in the ketamine/midazolam sedation group reported that they would prefer less sedation if the procedure were repeated ($P = .152$).

Staff Survey

Anonymous staff surveys were administered before and after the introduction of the ketamine sedation program. When asked what the acceptable maximum pain score is during a procedure, staff reported 3.7 (SD ± 1.4) at baseline and 3.2 (SD ± 1.6) at follow-up ($P = .260$). In general, staff reported that sedation with ketamine provided greater comfort to patients (Fig 4a–d). For the baseline survey, 8 (35%) of the

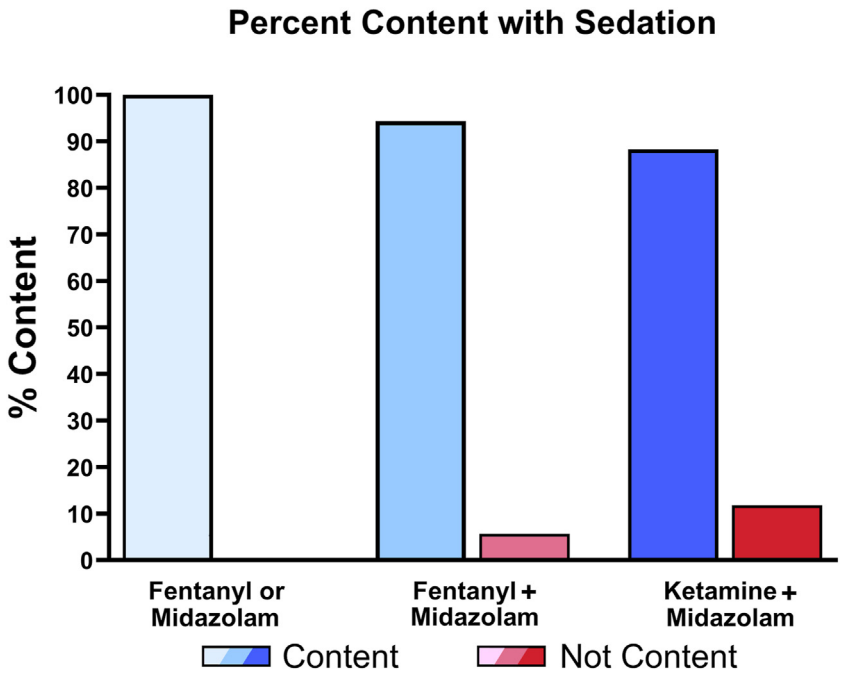

Figure 3. Patient satisfaction with sedation. There was no difference in reported satisfaction with sedation among sedation groups ($P > .05$).

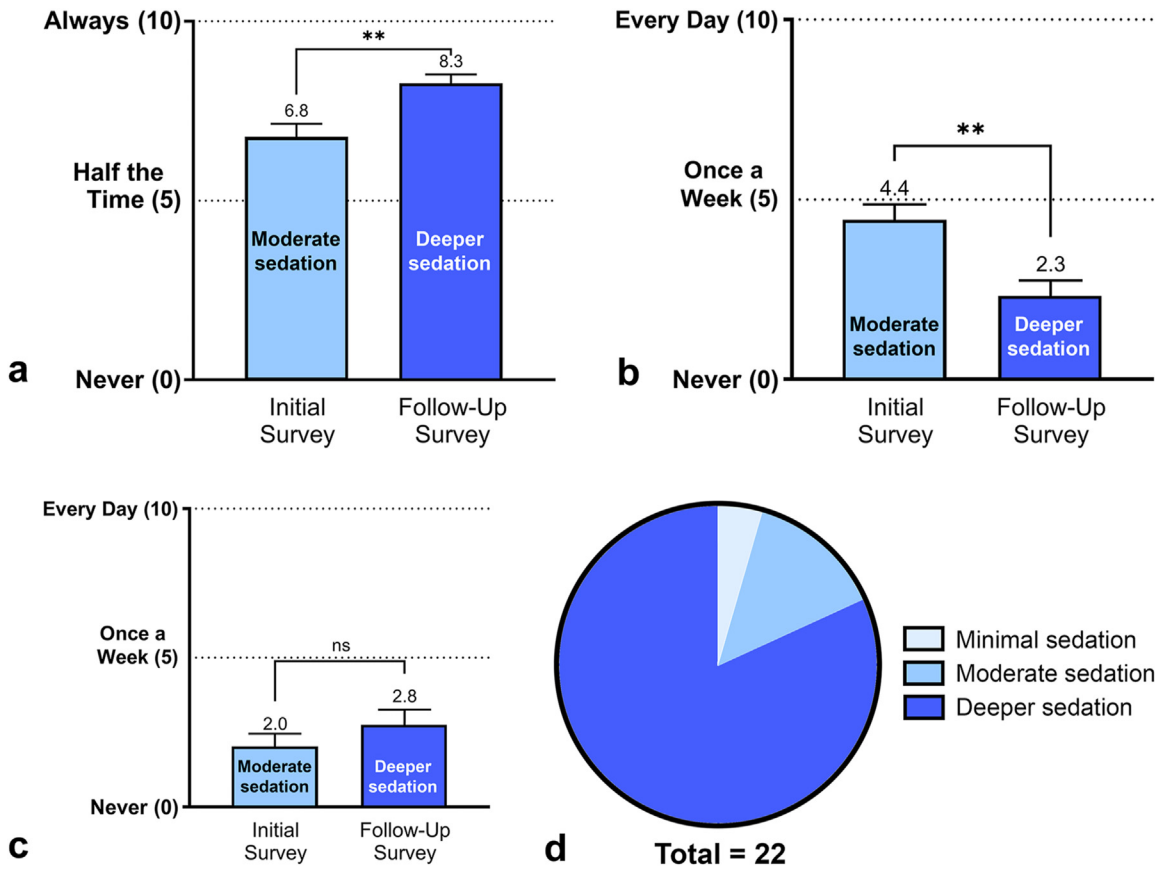

Figure 4. Staff surveys. Staff reported **(a)** that sedation with ketamine provided adequate comfort more often than conventional moderate sedation using fentanyl; **(b)** feeling uncomfortable with patients being in distress more commonly during procedures under moderate sedation using fentanyl compared with those under ketamine sedation; **(c)** observing side effects from moderate fentanyl and ketamine sedation uncommonly. **(d)** Most staff members endorsed that they would choose ketamine sedation if they underwent a painful procedure such as abscess drainage. $^{**}P \leq .01$.

23 staff members reported that they would not change the level of sedation offered to IR patients, and the remaining 15 (65%) endorsed wanting to give deeper levels of sedation during IR procedures. At the study conclusion, 18 (82%) of the 22 staff members reported that if given the option, they would choose ketamine sedation for themselves.

DISCUSSION

This study suggests that sedation with ketamine/midazolam administered by interventional radiologists without anesthesiology involvement was safe and effective. The study builds on previous work focusing on safety of ketamine/midazolam sedation for IR procedures (21) by comparing ketamine/midazolam and fentanyl/midazolam sedation. Pain scores after ketamine/midazolam sedation were reduced compared with fentanyl/midazolam sedation both during and after procedures, without increasing procedure duration or AE rates. Objective findings were affirmed by staff observations. After gaining familiarity with ketamine/midazolam sedation, most IR providers said they would choose ketamine sedation for themselves. Administering deeper sedation is routine for other nonanesthesiology providers. For example, ketamine is specifically prescribed by national guidelines put forth by the American College of Emergency Physicians (14). The ability to administer ketamine without an anesthesiologist would be particularly helpful for interventional radiologists, given that many IR procedures are brief but painful and there is an increasing shortage of anesthesiology providers (8,9). Data presented in this study lay the groundwork for future randomized trials and suggest that IR as a field might reconsider sedation guidelines and practices to improve patient-centered experience.

The study highlights a significant benefit of ketamine/midazolam sedation: postprocedural pain was also reduced. Decreased postprocedural pain after ketamine has been observed after oral and maxillofacial surgery and gastroenterology and emergency medicine procedures (4,11,22,23). Data collected from the postprocedural phone calls showed that most study participants were satisfied with either sedation regimen. However, statistically significant differences between the study groups could not be detected. This could be a consequence of a considerable loss to follow-up when attempting to reach participants in the days after a procedure by phone call. Future investigations may include an immediate postprocedural questionnaire in the periprocedural space to maximize participant involvement.

Another major benefit of ketamine is its preservation of respiratory reflexes, which makes this type of sedative ideal for use by nonanesthesiology providers performing procedures, without the distraction of potential respiratory compromise. In this study, there were no major respiratory AEs in the ketamine/midazolam sedation group. One downside of ketamine is its psychomimetic effects, such as agitation, hallucinations, and emergence reactions. Administering midazolam before ketamine reduces ketamine's psychomimetic effects (24), improving patient comfort and tolerance. Patients in this study who received ketamine/midazolam did not have an increased risk of blood pressure derangements during the procedure or of requiring antinausea medications during or after the procedure.

The study data suggest that ketamine/midazolam sedation is more helpful for certain types of IR procedures. No benefit of ketamine/midazolam sedation was observed in venous port placement and removal. For biopsy and drainage procedures, ketamine/midazolam sedation resulted in significantly reduced pain scores compared with fentanyl/midazloma sedation. Biopsy and drainage procedures, associated with higher levels of discomfort, are therefore better targets for future prospective studies aimed at optimizing sedation practices in IR.

The primary objective of procedural sedation is to ensure patient comfort, which, in turn, allows IR providers to perform procedures without distraction. Survey responses from IR providers in this study indicated that they believed maximum pain scores should not exceed 4 of the 10, aligning with existing literature on acceptable pain levels during procedures (25). Because procedures performed with fentanyl/midazolam sedation resulted in mean intraprocedural pain scores of 4 or greater, at least half of the patients experienced pain levels higher than what is considered reasonable by both the surveyed staff and the medical community at large. Reliance on fentanyl/midazolam sedation may be a pragmatic choice driven by the limited availability of anesthesiology services (9). This study highlights the need to expand access to deeper levels of sedation for interventional radiologists, particularly in settings where anesthesia providers are not readily available.

The study's limitations are due to its nonrandomized observational design. All cases involving any form of intravenous sedation were included, introducing potential bias, as patient characteristics and physician preferences influenced the selection of sedation type. The depth of sedation was not assessed reliably during the procedure. Collecting prospective data was onerous for clinical nurses engaged in standard of care duties, limiting the overall duration of the study. Furthermore, the study's use of postprocedural phone calls to assess patient satisfaction was limited by the challenge of reaching participants, hindering an accurate comparison of satisfaction between sedation groups. The study was not powered to detect differences in AE rates such as nausea and vomiting or respiratory compromise. For example, respiratory compromise occurs in 1% of IR procedures performed with moderate sedation (26). Even if the risk of respiratory compromise dropped to 0% with ketamine sedation, over 700 patients per group would be required to detect a difference with 80% power. Moreover, only adverse events that were moderate or worse were recorded, such that subjective experience of hallucinations and other minor complaints, could not be assessed. These limitations underscore the need for more robust, prospective randomized studies with dedicated research staff to better evaluate sedation practices and document sedation-related outcomes in IR, including depth of sedation and minor adverse events. Finally, there is no validated survey to assess IR providers'

perceptions of sedation effectiveness; the data generated in this study are hypothesis generating and could guide future efforts to create metrics evaluating IR staff views on sedation.

In conclusion, this prospective registry study suggests that deeper sedation with ketamine/midazolam is superior to moderate sedation with fentanyl/midazolam, with no added risk of AEs when administered in the absence of anesthesiology providers. IR providers with experience with both sedation regimens report that deep sedation with ketamine is superior and would prefer this type of regimen for themselves. Given the recent increasing anesthesiology provider shortages and public focus on patient-centered experience, the IR community at large could benefit from incorporating sedation with ketamine into routine practice.

AUTHOR INFORMATION

From the West Virginia School of Osteopathic Medicine (G.F.G.), Lewisburg, West Virginia; West Virginia University School of Medicine (Z.A.-A.), Morgantown, West Virginia; CAMC Institute for Academic Medicine (A.B.M., E.M.), and Interventional Radiology (M.K.), Department of Surgery, Charleston Area Medical Center, Charleston, West Virginia; and Interventional Radiology (A.R.D.), Department of Surgery, West Virginia University/Charleston Area Medical Center, Charleston, West Virginia. Received September 5, 2024; final revision received January 17, 2025; accepted January 27, 2025. Address correspondence to A.R.D., Division of Interventional Radiology, Department of Surgery, West Virginia University/Charleston Area Medical Center, 3200 MacCorkle Avenue SE, Charleston, WV 25304; E-mail: amy.deipolyi@camc.org

G.F.G. and Z.A-A. contributed equally to this work and are co-first authors.

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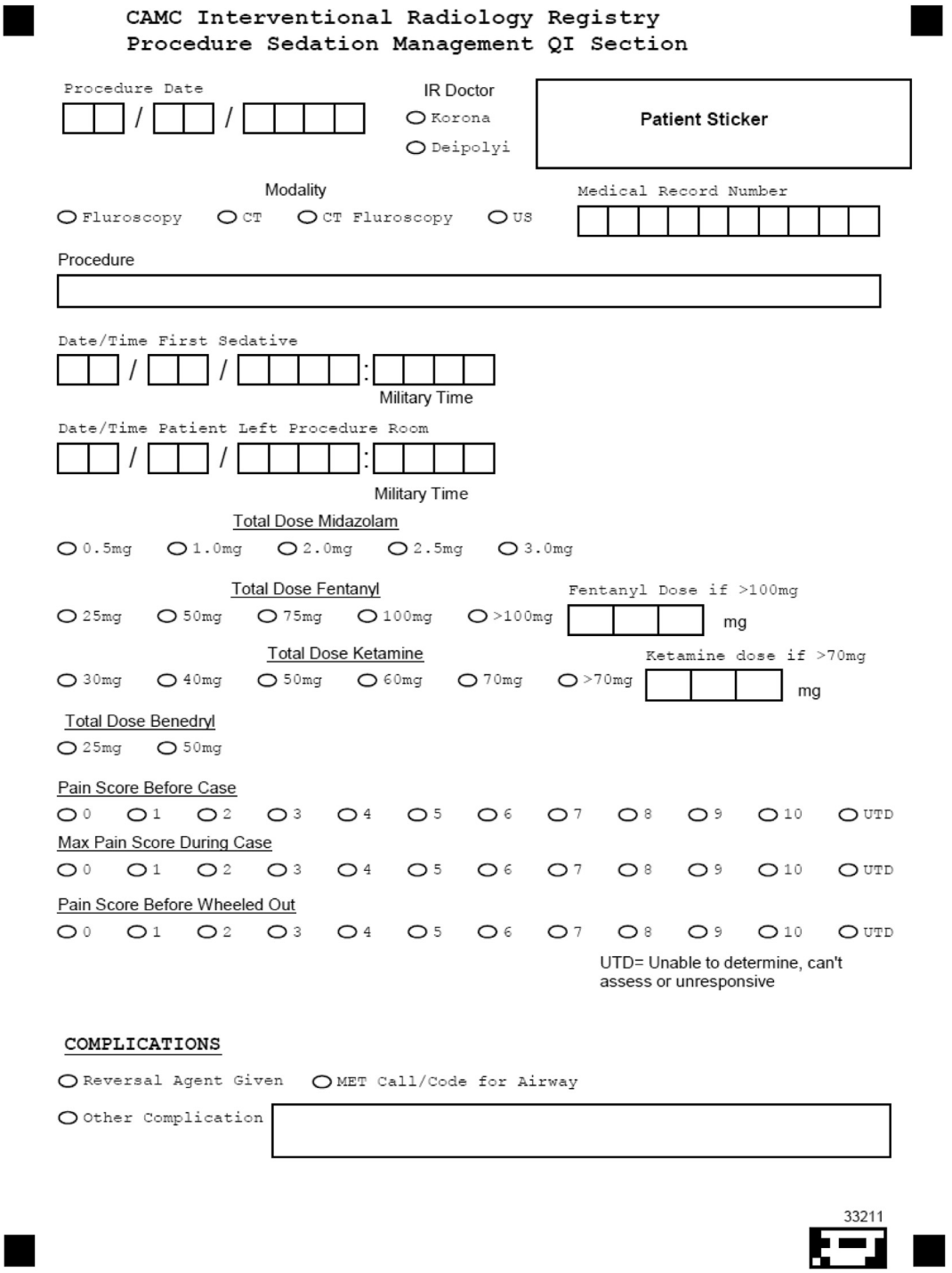

Figure E1. Registry collection data tool. Responses were scanned and converted into a database.