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Outpatient percutaneous image-guided microwave ablation with monitored anesthesia care: An exploratory study

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ABSTRACT

Purpose: To evaluate the feasibility, safety, and periprocedural perception of pain for a combination approach of moderate and deep sedation for image-guided percutaneous microwave ablation of both primary and secondary malignant lesions.

Methods: This was a retrospective study of 33 image-guided percutaneous microwave ablation procedures performed on 33 patients in an outpatient-based interventional radiology center. We used a combination of midazolam, fentanyl, propofol, and/or ketamine to achieve mild to moderate sedation for the procedure, and also to achieve deeper sedation as needed for the ablation portion.

Results: Technical success was achieved in all image-guided percutaneous microwave ablation procedures. Mean procedural time was 49.4 min. There were no major complications. Intraprocedural pain was absent in all patients. All 33 patients were deemed fit for discharge within 30 min following the procedure.

Conclusion: The combination approach of moderate and deep sedation for anesthesia during image-guided percutaneous microwave ablation is an advantageous option. This approach has a strong safety profile, good technical success, short procedure times, low levels of intraprocedural and post-procedural pain, and short recovery from anesthesia.

1. Introduction

Ablation, a needle-based treatment modality, involves the destruction of tissue using various methods such as cryoablation, thermal ablation (utilizing radiofrequency or microwave energy), chemical ablation, or irreversible electroporation.[1,2] Image-guided percutaneous thermal ablation (IPTA) has gained popularity as a minimally invasive technique for the treatment of primary and secondary tumors in soft tissue and bone, offering curative and palliative options.[2] Compared to traditional surgery, IPTA presents several advantages, including shorter recovery time, reduced complication rates, lower procedural costs, and the ability to perform it as an outpatient procedure.[3,4] Additionally, IPTA allows for easy repeatability in cases of residual or recurrent tumors.[2] Microwave ablation (MWA), in particular, is increasingly employed due to its ease of use, ability to achieve higher temperatures, larger ablation volumes, and shorter ablation durations compared to radiofrequency ablation (RFA).[1,5]

Different anesthesia techniques can be utilized for IPTA, including general anesthesia (GA), total intravenous anesthesia (TIVA), spinal anesthesia, and sedation using drugs such as midazolam, fentanyl, and propofol.[6,7] Historically, ablation procedures have been predominantly performed under GA or TIVA.[8,9] However, TIVA is associated with respiratory depression, and both GA and TIVA result in longer recovery times compared to moderate sedation.[6,10–12]

Deep sedation, defined as depression of the patient's consciousness such that they cannot be easily aroused, but are able to respond purposefully following repeated or painful stimulation.[13] Patients under deep sedation may have impaired ventilatory function and may require assistance maintaining a patent airway.[13]

Moderate sedation, defined as the depressing the patient's consciousness while maintaining the ability to respond to verbal and tactile stimuli, is considered safe for various interventional radiology procedures.[14] Patients under moderate sedation are able to maintain spontaneous respiration and a patent airway without assistance.[13] Nonetheless,

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moderate sedation may lead to irregular breathing patterns and increased patient movement, potentially complicating needle placement and the creation of an adequate ablation zone.[15,16] While moderate sedation for MWA has shown good technical success rates, pain during and/or after the treatment is a common issue.[1,17–20] A comparative study examining moderate sedation (using midazolam and narcotic analgesia), deep sedation (utilizing propofol and narcotic analgesia), and GA with narcotic analgesia revealed similar levels of technical success and pain perception for each arm.[21]

Existing literature on IPTA predominantly focuses on either moderate or deep sedation for both needle placement and ablation phases.[2,5,9,17,21] However, a combination approach involving both moderate and deep sedation, tailored to the specific portions of the procedure, may offer potential benefits. This approach could provide patients with a potentially painless experience by utilizing moderate sedation during needle placement and deep sedation during the ablation phase. Additionally, this combination approach may minimize the risk of respiratory depression (which can be associated with TIVA and deep sedation[13]) while promoting rapid recovery. A previous study has reported on a combination sedation approach, however, it employed complex and non-reproducible methods, such as slow weight-based infusions titrated to electroencephalogram (EEG) bi-spectral indices, requiring the use of flumazenil for reversal at the end of the procedure.[22]

In our center, the anesthesiologist generally administers monitored anesthesia care (MAC), which involves a combination of midazolam, fentanyl, propofol, and/or ketamine. This approach achieves mild to moderate sedation during the procedure and deeper sedation as needed for the ablation phase. To the best of our knowledge, this specific MAC-based combination sedation technique for ablation has not been previously described. This retrospective study aims to assess the feasibility, safety, and periprocedural pain perception of our combination sedation approach during image-guided percutaneous MWA of primary and secondary malignant lesions in an outpatient-based interventional radiology center.

2. Materials and methods

2.1. Study design and setting

This retrospective analysis was conducted at a single outpatient-based interventional radiology center in suburban Long Island, New York. The study was approved by an Institutional Review Board (IRB), and a waiver for informed consent was obtained due to the retrospective nature of the study. The analysis included 33 image-guided percutaneous MWA procedures performed on 33 patients between December 2021 and July 2022. All procedures were performed by a single interventional radiologist (MD) with over six years of experience in thermal ablation and over four years of experience in microwave ablation. Anesthesia was administered by a single anesthesiologist (PS) with over 18 years of experience. Our combination approach involved the use of midazolam, fentanyl, propofol, and/or ketamine to achieve mild to moderate sedation during the procedure, and deeper sedation as needed for the ablation portion. The deeper sedation was achieved primarily through a push dose of propofol with a small amount of fentanyl or ketamine immediately prior to initiation of ablation (or two push doses in cases with longer ablation times).

2.2. Inclusion and exclusion criteria

Inclusion criteria were patients who underwent IPTA of primary or secondary tumors in soft tissue or bone. Indications for treatment included both tumor destruction and palliation of pain. Included patients had complete documentation of anesthesia techniques, medication doses, intraprocedural and post-procedural vitals, and pain scores. Patients treated with ablations other than MWA were excluded. All ablations were performed using the Neuwave Microwave Ablation System (Ethicon; New Jersey, USA). The Neuwave Microwave Ablation System (Ethicon; New Jersey, USA) was used for all ablations, and intraprocedural CT imaging was performed using a GE Revolution EVO 64 slice CT Scanner (GE Healthcare; Chicago, Illinois, USA).

2.3. Variables

Patient characteristics, including age, sex, and body mass index (BMI), were recorded. The American Society of Anesthesiologists (ASA) score,[23] which assesses overall health on a scale of 1 to 6, and the Mallampati score,[24] which indicates potential difficulty in tracheal intubation on a scale of 1 to 4, were also recorded. Other variables included the target organ for ablation, primary cancer type, and indication for ablation (tumor destruction, pain control). Procedural approaches such as same-day embolization, concurrent biopsy, and the use of advanced techniques were documented. Lesion number and size, ablation probe type and number, ablation duration, maximum wattage, and total procedural time were recorded. Technical success criteria were based on intraprocedural CT imaging and 1-month follow-up contrast-enhanced CT for soft tissue lesions, and completion of intended ablation cycles for bone lesions. Anesthesia types and dosages were recorded. Pain scores were assessed using a visual analogue scale ranging from 0 (no pain) to 10 (maximum pain), including pre-procedure, intra-procedure, postprocedure, and discharge pain scores. Complications such as bleeding, respiratory insufficiency, and pneumothorax were documented. Postprocedure recovery room variables included medications administered and initial and 30-minute modified Aldrete scores, which assess the physical status of patients recovering from anesthesia on a scale of 0 to 10, with scores of 9 or 10 indicating readiness for discharge.[25]

2.4. Statistical analysis

Mean and standard deviation were used to describe the continuous variables. Frequency and percentage were used to describe the categorical variables. The Pearson correlation was used to correlate the continuous variables of body mass index and total procedure time. Sex comparisons were performed with analysis of variance for variables with a normal distribution and the Mann Whitney test for variables with a skewed distribution. Summary data comparisons for the current study to the study by Puijk et al.[21] were performed with the independent samples *t*-test for continuous variables and the Fisher's exact test for categorical variables. All *p*-values were two tailed with alpha for significance at $p < 0.05$. Statistical analysis was conducted using IBM SPSS Statistics version 28 (IBM Corporation, 2021) and Stata SE version 17 (College Station, TX, 2022).

3. Results

Table 1 shows the sample characteristics. Mean age was 67.2 years and 54.5 % of patients were male. Mean BMI was 27.7. Mean ASA classification of 3.1. Mean Mallampati score was 2.1. The kidney was the target organ for ablation for 57.6 % of procedures and renal cell was the type of cancer for 63.6 %.

Table 2 shows treatment and related characteristics of those undergoing ablation. The mean number of lesions treated was 1.0 with 32 of 33 patients having only one lesion treated. The mean size of treated lesions was 2.6 cm. Mean procedural time was 49.4 min and mean ablation time was 5.2 min. Technical success was achieved for 100 % of procedures. Propofol ($n = 30$), ketamine ($n = 28$), and midazolam ($n = 32$) were the most commonly used anesthetics. Severe pain with VAS ≥ 5 occurred in 9.1 % of patients preprocedure, 0.0 % intraprocedure, 3.0 % postprocedure and 3.0 % at discharge. Modified Aldrete Scores showed that 90.9 % and 100 % of patients met anesthesia criteria for discharge on arrival to postprocedural recovery and after 30 min respectively. There were no major complications. There was one minor complication

Table 1
Demographic characteristics of the 33 patients with ablation.

Variable	M (SD) or frequency (percentage)
Age (years) [mean]	67.2 (13.06)
Sex (male)	18 (54.5)
Body mass index (kg/m^2) [mean]	27.7 (4.70)
ASA classification [mean]	3.1 (0.33)
Mallampati score [mean]	2.1 (0.33)
Target organ for ablation	
Kidney	19 (57.6)
Liver	6 (18.2)
Bone	7 (21.2)
Soft tissue	1 (3.0)
Cancer	
Renal	21 (63.6)
Breast	5 (15.2)
Colorectal	2 (6.1)
Lung	2 (6.1)
Other	3 (9.1)
Indication	
Tumor destruction	29 (87.9)
Pain control	4 (12.1)

Note: M = mean, SD = standard deviation, ASA = American Society of Anesthesiologists.

of bleeding where hemostasis was achieved intraprocedurally.

BMI was not significantly correlated with total procedure time ($r = -0.07$, $p = 0.71$). Table 3 shows no significant sex differences for anesthesia, pain, and the modified Aldrete score. Table 4 shows comparisons from the current study to the Puijk et al. study.[21]

4. Discussion

Our study demonstrated the feasibility and safety of our combination anesthesia approach for percutaneous image-guided MWA. We achieved technical success in all cases, with short mean procedural times of 49.4 min. The low incidence of complications, including only one case of self-limited bleeding, further supports the safety of our approach. Pain perception was minimal, with no severe pain reported during the procedure.

The high level of technical success achieved in our study suggests that deeper levels of anesthesia with physician-controlled paralysis and breath holds may not be necessary for MWA. This finding aligns with previous studies that used different types of anesthesia.[21,22,26] Our combination sedation approach, involving moderate sedation for the majority of the procedure and deep sedation during the ablation, yielded significantly shorter ($p < 0.001$) procedural times (49.4 min) compared to studies using either moderate sedation (105 min) or deep sedation (97 min).[21] One potential factor contributing to the shorter procedural times in our study is the prior shared experience between the performing interventional radiologist and the anesthesiologist.

The majority of our patients recovered from anesthesia upon arrival to the post-procedural recovery room and all of the patients recovered within 30 min. We attribute the short recovery times in our study to the low doses of anesthetic drugs used with our approach, as well as primarily using propofol, a short-acting drug, during the deep sedation portion.

Our combination sedation approach demonstrated a good safety profile, with no major complications and no instances of respiratory insufficiency requiring ventilation or reversal agents. Puijk et al. had five complications occurring in 114 total patients (4.4 %) including hemorrhage requiring embolization, pneumothorax which resolved spontaneously, and respiratory insufficiency which required emergent intubation.[21] It is worth noting that the distinction in healthcare settings between our study and the Puijk study, with the former conducted at an outpatient-based interventional radiology center and the latter at a large hospital, could have influenced case selection and patient characteristics, potentially contributing to the divergent rates of complications

Table 2
Treatment and related characteristics of those undergoing ablation.

Variable	M (SD) or frequency (percentage)
Treatment	
Embolization same day (yes)	4 (12.1)
Concurrent biopsy (yes)	13 (39.4)
Advanced techniques required (yes)	7 (21.2)
Lesions (number) [mean]	1.0 (0.17)
Diameter (cm) [mean]	2.6 (1.05)
Probes (number) [mean]	1.2 (0.36)
Probe type	
PR15	5 (15.2)
PR15XT	23 (69.7)
PR20	5 (15.2)
Second probe (yes)	5 (15.2)
Ablation time (minutes) [mean]	5.2 (3.01)
Maximum ablation energy applied (watts) [mean]	62.7 (11.33)
Total procedure time (minutes) [mean]	49.4 (15.08)
Technical success (yes)	33 (100.0)
Anesthesia	
Propofol (mg) [mean] (n = 30)	63.3 (31.55)
Ketamine (mg) [mean] (n = 28)	32.8 (29.12)
Midazolam (mg) [mean] (n = 32)	3.6 (1.50)
Fentanyl (mcg) [mean] ($n = 14$)	114.3 (36.31)
Toradol (mg) [mean] (n = 2)	30.0 (0.00)
Benadryl (mg) [mean] (n = 3)	25.0 (0.00)
Zofran (mg) [mean] ($n = 10$)	4.0 (0.00)
Pain	
VAS preprocedure [mean]	0.5 (1.66)
VAS intraprocedure maximum [mean]	0.0 (0.00)
VAS postprocedure maximum [mean]	0.6 (1.37)
VAS discharge [mean]	0.4 (1.27)
VAS preprocedure $\geq$ 5 (yes)	3 (9.1)
VAS intraprocedure maximum $\geq$ 5 (yes)	0.0 (0.0)
VAS postprocedure maximum $\geq$ 5 (yes)	1 (3.0)
VAS discharge $\geq$ 5 (yes)	1 (3.0)
Complications	
Bleeding (yes)	1 (3.0)
Respiratory insufficiency (yes)	0.0 (0.0)
Pneumothorax (yes)	0.0 (0.0)
Post-procedure recovery room	
Medications given (yes)	7 (21.2)
Modified Aldrete Score initial [mean]	9.4 (0.65)
Modified Aldrete Score at 30 min [mean]	9.8 (0.39)
Modified Aldrete Score initial ready for discharge	30 (90.9)
Modified Aldrete Score at 30 min ready for discharge	33 (100.0)

Note: M = mean, SD = standard deviation, VAS = Visual Analogue Scale, Bleeding complication was small with hemostasis achieved intraprocedurally.

observed. We suggest that the combination sedation approach employed in our study may have also played a role in mitigating the occurrence of respiratory insufficiency.

The mean dose of propofol administered was much lower ($p < 0.001$) in our study (63.3 mg) than in both the general anesthesia arm (1160.0 mg) and the propofol sedation arm (706.0 mg) of the Puijk et al. study.[21] This very large difference may be attributable to the low doses used during moderate sedation for the majority of the procedure using our combination anesthesia approach. Deep sedation and higher doses of propofol were reserved for the ablation phase. Despite the reduced anesthetic doses, our combination approach allowed us to effectively manage patient pain. Although propofol has rapid onset and offset of action, there can be rapid and sometimes unpredictable progression from deep sedation to general sedation.[27] The pharmacologic variability can be magnified in elderly patients and with the concurrent use of other drugs.[27] It is possible that by reducing the overall dose of propofol, the risk of respiratory insufficiency may also be reduced. In this study there were no episodes of respiratory insufficiency, versus 1.7 % in the propofol sedation arm of the Puijk study.[21]

In terms of intraprocedure pain, our study demonstrated a mean

Table 3
Sex comparisons for anesthesia, pain, and Modified Aldrete Score.

Variable	Female M (SD) ($n = 15$)	Male M (SD) ($n = 18$)	p-Value
Anesthesia			
Propofol (mg) [mean]	55.4 (21.45)	69.4 (36.99)	0.41
Ketamine (mg) [mean]	24.2 (11.44)	39.3 (36.40)	0.42
Midazolam (mg) [mean]	3.4 (1.45)	3.8 (1.54)	0.38
Pain			
VAS preprocedure [mean]	0.7 (1.94)	0.3 (1.41)	0.74
VAS intraprocedure maximum [mean]	0.0 (0.00)	0.0 (0.00)	–
VAS postprocedure maximum [mean]	0.8 (1.82)	0.4 (0.86)	0.99
VAS discharge [mean]	0.8 (1.82)	0.0 (0.00)	0.34
Post-procedure recovery room			
Modified Aldrete Score initial [mean]	9.5 (0.64)	9.3 (0.67)	0.42
Modified Aldrete Score at 30 min [mean]	9.9 (0.35)	9.8 (0.43)	0.68

Note: M = mean, SD = standard deviation, VAS = Visual Analogue Scale. Anesthesia variables have sample sizes ranging from 28 to 32 patients. Analysis of variance conducted for Midazolam and Modified Aldrete Score initial. All other analyses conducted with the Mann Whitney test.

Table 4
Comparisons from current study to Puijk et al. study.

Variable	Current study M (SD) or # (%)	Puijk et al. study M (SD) or # (%)	p-Value
VAS postprocedure ≥ 5 (yes)	1 (3.03)	12 (10.53)	0.30
Complications (yes)	1 (3.03)	5 (4.39)	1.00
Total procedure time (minutes) [mean]	49.4 (15.08)	108.0 (69.00)[a]	<0.001
Total procedure time (minutes) [mean]	49.4 (15.08)	97.0 (36.00)[b]	<0.001
Total procedure time (minutes) [mean]	49.4 (15.08)	105.0 (63.00)[c]	<0.001
Propofol (mg) [mean]	63.3 (31.55)	1160.0 (637.00)[a]	<0.001
Propofol (mg) [mean]	63.3 (31.55)	706.0 (344.00)[b]	<0.001

Note: M = mean, SD = standard deviation, VAS = Visual Analogue Scale. Complications were bleeding, respiratory insufficiency, or pneumothorax.
[a] General anesthesia.
[b] Propofol sedation.
[c] Midazolam.

maximum VAS score of 0, which is lower than other studies employing moderate and deep sedation for percutaneous MWA.[18,20,21] A Korean study predominantly utilizing deep sedation reported a mean VAS score of 5.55.[20] A Chinese study utilizing moderate sedation for MWA reported mean VAS scores of 5.18 and 3.48 in its two respective arms.[18] In the Puijk et al. study, subjective measures were employed for intraprocedure pain assessment, recording pain rates of 0.00 % in the general anesthesia arm, 1.67 % in the propofol arm, and 34.38 % in the midazolam arm.[21] By employing our combination approach, we were able to provide pain control that approached levels described with general anesthesia and deep sedation, all without the need for prolonged administration of higher doses of medications.

Our study did not observe any significant sex differences in anesthesia doses, pain scores, or Modified Aldrete Scores. While previous research has reported conflicting results regarding gender differences in perioperative pain perception, our small sample size limits definitive conclusions, and further investigation with larger sample sizes is warranted.[28,29]

In conclusion, the combination approach of moderate and deep sedation for anesthesia during image-guided percutaneous MWA is a viable option. This approach offers a strong safety profile, high technical success rates, short procedure times, minimal pain perception, and rapid recovery from anesthesia. Future research with larger sample sizes and comparative analysis is needed to further validate and refine our findings.

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