

Efficiency of Using a Fixed-Wrist Splint in Patients with Intra-Arterial Catheterization to Monitor Arterial Blood Pressure During a Surgical Intervention: A Pilot Study

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Abstract

OBJECTIVES: This study is a pilot research with objectives to study the effectiveness of using a fixed-wrist splint in patients undergoing intra-arterial catheterization to monitor the patient's arterial blood pressure from the artery at the wrist during surgery and to assess the anesthesiologists' satisfaction in using the fixed-wrist splint.

MATERIALS AND METHODS: This study was conducted as a pilot case series describing the use of a fixed-wrist splint designed to be suitably inclined to between 30° and 40° during intra-arterial catheterization in surgical procedures. The sample was 8 patients undergoing surgery with intra-arterial catheterization at the wrist, and 8 anesthesiologists who used the fixed-wrist splint during the procedures completed the satisfaction questionnaire. The study was conducted between 22 October 2021 and 4 February 2023. The effectiveness was measured by monitoring the count of the arterial line dislodgement, the number of catheter reinsertion, the ability to consistently monitor the blood pressure effectively, and the satisfaction of anesthesiologists that used the device. Data were summarized using descriptive statistics. Continuous variables were presented as median and interquartile range, while categorical variables were presented as frequency and percentage.

RESULTS: A total of 8 patients were included. The median age of the patients was 57 years (IQR 52.5–68.5). The median body weight was 64.6 kg (Interquartile Range (IQR) 59.6–71.4), the median height was 166.5 cm (IQR 159.5–171.0), the median wrist circumference was 16.25 cm (IQR 15.75–16.5). Among the five patients with available measurements, the median wrist-splint angle was 33° (IQR 31–36°). Six of the patients were male (75%), and two were female (25%). Six of the patients underwent heart surgery (75%), and 2 of the patients underwent neurosurgery (25%). Of all the patients who used the fixed-wrist splint, 100% experienced no arterial line dislodgement, 100% required no catheter reinsertion, and blood pressure was monitored successfully in all cases (100%). Additionally, 8 anesthesiologists reported high satisfaction with the device. Median item scores ranged from 4 to 5 across the six satisfaction domains, with the highest score observed for safety [5 (IQR 5–5)]. The median total satisfaction score was 27.5 out of 30 (IQR 25.0–29.3), and all respondents were willing to continue using the device (100%).

CONCLUSION: In this pilot case series, the use of the fixed-wrist splint in patients undergoing intra-arterial catheterization was feasible. No arterial line dislodgement or catheter reinsertion occurred, and continuous arterial blood pressure monitoring was successfully maintained in all cases. Additionally, anesthesiologists were satisfied with the device, especially regarding safety, practicality, and the benefit of using the fixed-wrist splint.

Keywords: wrist splint, Intra-arterial catheterization, arterial blood pressure, blood pressure monitoring, surgical intervention

Arterial Blood Pressure (ABP) can be monitored non-invasively using a blood pressure monitor (non-invasive blood pressure (NIBP)), or directly monitored by Invasive Blood Pressure (IBP), known as arterial line (A-line) which involves inserting a catheter into the patient's artery to directly monitor changes in blood

pressure at all times, this method is typically only used in patients in critical conditions, e.g., those with very low blood pressure, stroke, those requiring administration of blood pressure-regulating medications, those with arterial blood gas conditions, those under surgery and needs their blood pressure closely monitored, or patients for whom their blood pressure cannot be measured NIBP.¹

The artery commonly chosen for this purpose is the radial artery, located in the wrist area, it is preferred due to its ease of access¹, ease of care, and high success rate. The nursing role in intra-arterial catheterization includes maintaining the arterial line in an appropriate position. Based on the operation of an anesthesiologist, it was found that the optimal position to insert the catheter is to keep the wrist and the hand tilted up slightly (Mild dorsiflexion), then supporting the wrist with a roll of cloth or paper placed underneath², after the catheterization is complete and the insertion site has been covered with a sterile material, it is crucial that the arterial line leading out from the radial artery is properly supported, preventing it from folding, bending, or dislodging. The patient's wrist and hand must remain slightly dorsiflexed during direct monitoring of the arterial blood pressure changes. If the wrist is overly tilted, it can cause the arterial line to become dislodged, which risks it becoming clogged. If this occurs, the blood pressure cannot be read accurately and the patient risks requiring catheter reinsertion.³

The wrist splint for intra-arterial catheterization currently in use faces issues with the supporting role of cloth or paper not being suitable for all patients due to its fixed size. Several patients are unable to tilt their wrist up to a suitable angle, creating a gap between the back of their hand and the supporting cloth, as a result, more cloth must be inserted to fill the gap. Additionally, the patient's posture can also cause the wrist area with the arterial line attached to move, or bend, which can cause the arterial line to break, or dislodge, making the blood pressure inaccurate or unreadable.⁴

Nurse anesthetist researchers, with advice from physicians have made a joint effort to devise a new wrist splint designed to effectively support the patient's hand during the intra-arterial catheterization procedure, and conducted an experimental study of the device to improve its effectiveness, including:

1. The appropriate angle to measure the blood pressure from the artery at the wrist area during an operation. Athlani et al. evaluated several wrist positions and found that flexor tendon relaxation was maintained with the wrist positioned at 30° or 45° of extension when metacarpophalangeal joint flexion was maintained.⁵
2. Strength testing the wrist splint in terms of weight bearing by applying a load that affects the shape and angle of the splint. The test involves setting the initial angle of the splint to 40°, then placing a sandbag at the corner to replicate the weight of a patient's hand. Based on the load test, the wrist splint supported a load equivalent to the estimated hand weight of a person weighing up to 615 kg, calculated using the percentage of total body weight represented by the hand.⁶ The resulting angle of the wrist splint after placement of the sandbag was between 30° and 40°.

Based on the review of literature related to innovations specifically designed to support patients' wrists and reduce instability of arterial lines during intra-arterial catheterization in surgical settings, previous studies have shown limitations in the ability to adjust the wrist angle to accommodate individual patients. Although several wrist support devices have been developed, many provide fixed positioning and lack flexibility for patient-specific anatomical differences. In Thailand, only a few studies have reported the use of fixed-wrist splint to support the patient's hand during the intra-arterial catheterization procedure.^{7,8} In response to this gap, the anesthesiology team developed an adjustable fixed-wrist splint using readily available and low-cost materials, including reused endotracheal tube stylets, cardboard, synthetic padding, and non-woven wrapping material. The device was reinforced with three U-shaped stylets to provide structural rigidity, padded for patient comfort, and enclosed in a tailored non-woven sleeve with securing straps at the palm and forearm. Measuring approximately 9×31 cm, the splint was designed to permit adjustable wrist extension between 30° and 45°, informed by biomechanical evidence on flexor tendon relaxation.

A pilot study has been initiated to explore the feasibility of using this fixed-wrist splint in patients undergoing arterial line placement at the wrist for continuous blood pressure monitoring during surgery. The aim of this study is to evaluate the effectiveness of the wrist splint, with the expectation that the findings will help refine the device and support further development of this innovation to enhance its clinical applicability and effectiveness.

This study aimed to evaluate the effectiveness of a fixed wrist splint in patients undergoing intra-arterial catheterization for intraoperative blood pressure monitoring and to assess anesthesiologists' satisfaction with its use for arterial line support during surgery.

Materials and Methods

This study was conducted as a pilot case series.

Equipment used in the study

1. **Fixed-wrist splint prototype:** The innovative fixed-wrist splint prototype was constructed from readily available materials, including reused endotracheal tube stylets, cardboard, synthetic padding, and non-woven wrapping material. The device was reinforced with three U-shaped stylets for structural rigidity, padded for patient comfort, and enclosed in a non-woven sleeve with securing straps at the palm and forearm. Measuring approximately 9 × 31 cm, the splint was designed to maintain adjustable wrist extension between 30° and 40°, corresponding to the intended wrist position for intra-arterial catheterization. The splint was placed beneath the wrist on the arterial line side, with minor angle adjustments made as needed. Following catheterization, the straps were secured to maintain wrist stability during surgery (Figure 1).



Figure 1: Fixed-wrist splint applied in position during intra-arterial catheterization.

2. **Anesthesiologists' satisfaction questionnaire:** Anesthesiologists' satisfaction with the fixed-wrist splint was assessed postoperatively using a researcher-developed questionnaire.⁹⁻¹⁰ The questionnaire consisted of six items evaluating compliance with intended use, adequacy, benefits, ease of use, safety, and overall suitability. Each item was rated on a 5-point Likert scale ranging from 1 (least satisfied) to 5 (highly satisfied). Total scores ranged from 6 to 30, with higher scores indicating greater satisfaction. An additional item assessed willingness to continue using the device. Formal validity and reliability testing were not performed in this pilot study.
3. **Data collection form:** A structured data collection form was used to record demographic characteristics, including age, sex, body weight, height, type of surgery, side of arterial catheter insertion, and wrist circumference, together with procedural outcomes such as arterial line dislodgement, catheter reinsertion, and the ability to maintain continuous arterial blood pressure monitoring during surgery.

Study Population and Eligibility Criteria

The study population comprised adult patients undergoing surgical procedures requiring intra-arterial catheterization at the wrist for intraoperative arterial blood pressure monitoring at Bangkok Hospital Chiang Mai. Anesthesiologists who used the fixed-wrist splint during these procedures were also included in the satisfaction assessment.

Due to the absence of prior reference data regarding the use of a fixed-wrist splint in the operative setting, sample size calculation was not performed. This pilot case series used consecutive sampling, with an intended target of up to 30 cases or a maximum study duration of two years, whichever occurred first.

- **Patient group:** Eligible participants were patients aged ≥ 20 years who underwent intra-arterial catheterization at the wrist during surgery, were able to communicate in Thai, and were Thai nationals. Patients withdrawn due to illness, death, or personal reasons were excluded.
- **Anesthesiologist group:** Eight anesthesiologists who used the fixed-wrist splint during intra-arterial catheterization procedures were included to assess user satisfaction. No exclusion criteria were applied.

During the study period (22 October 2021 to 4 February 2023), 8 eligible patients and 8 anesthesiologists were enrolled.

Ethical Considerations

This study was reviewed and approved by the Institutional Review Board (IRB) of Bangkok Hospital Chiang Mai COA no. 2022-002 prior to data collection. Written informed consent was obtained from all participants before enrollment. Participation was voluntary, and all data were handled confidentially to protect participants' privacy and anonymity.

Data Collection

After the patient entered the operating room and standard preparations were completed, the fixed-wrist splint was adjusted to maintain wrist extension between 30° and 40° and positioned beneath the dorsal aspect of the wrist on the side selected for intra-arterial catheterization. Minor adjustments were made as needed to fit the patient's anatomy. Following successful arterial catheterization and arterial line connection, the securing straps at the palm and forearm were tightened to maintain wrist stability throughout surgery.

Arterial blood pressure monitoring was performed continuously during surgery, and anesthesiologists recorded monitoring data at 5-minute intervals. After surgery, anesthesiologists completed the satisfaction questionnaire, and researchers finalized data collection using the questionnaire responses and medical records.

Data were collected from 22 October 2021 to 4 February 2023 using medical records, direct measurements, and structured questionnaires. Collected variables included age, sex, body weight, height, type of surgery, side of arterial catheter insertion, wrist circumference, arterial line dislodgement, catheter reinsertion, and the ability to maintain continuous arterial blood pressure monitoring during surgery.

Data analysis

Patients' personal data, including sex, type of surgery, and wrist side, were summarized using descriptive statistics and presented as frequency and percentage. Demographic characteristics, including age, body weight, height, and wrist circumference, were summarized using median and interquartile range.

The effectiveness of the fixed-wrist splint was evaluated based on arterial line dislodgement, catheter reinsertion, ability to maintain continuous arterial blood pressure monitoring, anesthesiologists' satisfaction, and splint angle. Arterial line dislodgement, catheter reinsertion, and maintenance of continuous arterial blood pressure monitoring were summarized using descriptive statistics and presented as frequency and percentage.

Anesthesiologists' satisfaction was assessed using a 6-item questionnaire evaluating compliance with intended use, adequacy, benefits, ease of use, safety, and overall suitability. Each item was rated on a 5-point Likert scale ranging from 1 (least satisfied) to 5 (highly satisfied). Total scores ranged from 6 to 30, with higher scores indicating greater satisfaction. Satisfaction scores were converted into percentages and interpreted as high (70–100%), moderate (34–69%), or low satisfaction (0–33%). Satisfaction scores and splint angle measurements were presented as median and interquartile range. Willingness-to-use data were summarized using frequency and percentage.

Results

A total of 8 patients were enrolled in the study, and 8 anesthesiologists used the device and completed the satisfaction questionnaire. The median patient age was 57 years (IQR 52.5–68.5). Median body weight, height, and wrist circumference were 64.6 kg (IQR 59.6–71.4), 166.5 cm (IQR 159.5–171.0), and 16.25 cm (IQR 15.75–16.5), respectively. Six patients were male (75.0%) and two were female (25.0%). Regarding the type of surgery, 6 patients underwent cardiac surgery (75.0%) and 2 underwent neurosurgery (25.0%). Arterial catheterization was performed on the right wrist in 5 patients (62.5%) and on the left wrist in 3 patients (37.5%). Baseline demographic and clinical characteristics are summarized in Table 1.

Out of 8 patients, 100% experienced no arterial line dislodgement, 100% required no catheter reinsertion, and arterial blood pressure was continuously monitored in all cases (100%), as shown in Table 2.

Anesthesiologists' satisfaction with the use of the fixed-wrist splint was assessed using a 6-item Likert-scale questionnaire. The median item scores were 5 (IQR 4–5) for compliance of the wrist splint with its intended use, 4 (IQR 4–5) for adequacy, 5 (IQR 4–5) for benefits of using the wrist splint, 4.5 (IQR 4–5) for ease of use, 5 (IQR 5–5) for safety, and 4 (IQR 4–5) for overall suitability. The median total satisfaction score was 27.5 out of 30 (IQR 25.0–29.3), corresponding to a high level of satisfaction. All respondents indicated willingness to continue using the fixed-wrist splint (8/8, 100%), as shown in Table 3.

Based on measurements of the suitable wrist splint angle from 5 patients, the angle ranged from 30° to 37°, and the median angle was 33° (IQR 31°–36°). Angle data were available for only 5 patients because wrist-splint angle measurement was added after a protocol amendment during the study period; therefore, the first 3 patients did not have this variable recorded.

Table 1: Patient demographic and clinical characteristics (n = 8).

Characteristics	Value
Age (years)	
Median	57.0
IQR	52.5–68.5
Weight (kg)	
Median	64.6
IQR	59.6–71.4
Height (cm)	
Median	166.5
IQR	159.5–171.0
Wrist circumference (cm),	
Median	16.3
IQR	15.8–16.5
Sex, n (%)	
Male	6 (75.0)
Female	2 (25.0)
Type of surgery, n (%)	
Cardiac surgery	6 (75.0)
Neurosurgery	2 (25.0)
Catheter insertion side, n (%)	
Right wrist	5 (62.5)
Left wrist	3 (37.5)

Note: Continuous variables are presented as median and interquartile range (IQR). Categorical variables are presented as number and percentage.

Table 2: Procedural characteristics of intra-arterial catheterization using the fixed-wrist splint (n = 8)

Procedural Characteristics	n (%)
Arterial line dislodgement	
Not observed	8 (100.0)
Observed	0 (0.0)
Catheter reinsertion	
Not required	8 (100.0)
Required	0 (0.0)
Continuous arterial blood pressure monitoring	
Able to read	8 (100.0)
Unable to read	0 (0.0)

Table 3: Anesthesiologists' satisfaction with the fixed-wrist splint (n = 8).

Satisfaction Items	Median (IQR)
Compliance of the wrist splint with its intended use	5.0 (4.0–5.0)
Adequacy of the wrist splint	4.0 (4.0–5.0)
Benefits of using the wrist splint	5.0 (4.0–5.0)
Ease of use of the wrist splint	4.5 (4.0–5.0)
Safety of the wrist splint	5.0 (5.0–5.0)
Overall suitability	4.0 (4.0–5.0)
Total satisfaction score (out of 30)	27.5 (25.0–29.3)

Note: Data are presented as median and interquartile range (IQR). All anesthesiologists (8/8, 100%) reported willingness to continue using the wrist splint.

Table 4: Angle of the fixed-wrist splint used during intra-arterial catheterization (n = 5)

Characteristics	Value
Angle of fixed-wrist splint (degrees), median (IQR)	33 (31–36)

Note: Data are presented as median and interquartile range (IQR).

Discussion

This pilot case series has shown that the use of a fixed-wrist splint in patients with arterial catheterization during surgery can aid in monitoring blood pressure; none of the patients encountered arterial line dislodgement nor did they need catheter reinsertion because the fixed-wrist splint may have helped to stabilize the wrist position, thus reducing movement at the catheter insertion site. Therefore, the use of a fixed-wrist splint showed favorable outcomes in supporting continuous arterial blood pressure monitoring. This result aligns with the study of Panwassana et al.,⁷ which focuses on studying a wrist splint, “A-line Strong” that the team has created. They have found that the 2nd iteration of their wrist splint can also effectively prevent the arterial line from dislodging in all patients (100%), and arterial blood pressure was continuously monitored as well. Additionally, this result also aligns with another study on using the “A-line wrist splint” prototype of Lerdsin Hospital⁸, in which a similar splint was used in 221 patients; no arterial line rupture or dislodgement was observed, potentially contributing to more reliable arterial blood pressure monitoring.

While these two devices having demonstrated positive clinical outcomes, they were specifically designed as medical devices with established structures and materials. In contrast, the fixed-wrist splint evaluated in this study was developed using readily and easily available and reusable materials generally found in the operating room, resulting in minimized production costs. The splint can be manually adjusted to achieve an optimal wrist extension angle for each individual patient, thereby enhancing its adaptability during clinical use. Even though the splint is constructed from reused materials, it is designed as a single-use device, which may reduce the risk of cross-contamination and infection attributed to repeated use. The development of the fixed-wrist splint based on real-world clinical needs may help overcome challenges in arterial line stabilization by providing steady wrist positioning and minimizing mechanical stress at the catheter insertion site. These attributes emphasize the potential benefits of this innovation as a feasible, cost-saving, and adaptable alternative to existing wrist stabilization devices.

The study on anesthesiologists’ satisfaction on using the fixed-wrist splint on patients with arterial catheterization to monitor blood pressure at the wrist during surgery can be summarized as follows: anesthesiologists are satisfied with the splint used in the study, specifically in regards to safety, benefits, adequacy, ease of use, compliance with use case, and willingness to continue using the splint, concluding that the wrist splint is effective and suitable for use in patients, specifically in aiding arterial catheterization during surgery. It can be discussed that the high level of anesthesiologists’ satisfaction reflects the clinical practicality of the fixed-wrist splint in the intraoperative setting. The favorable feedback relating to safety and usability suggests that the splint does not disrupt routine anesthetic procedures and can be smoothly integrated into standard practice. These findings are consistent

with previous literature highlighting that the clinical acceptability of wrist support devices depends not only on their ability to stabilize the arterial line, but also on their usability and safety in routine practice. Hanrahan et al.⁴ reported that safe radial arterial line management depends on effective wrist support and stabilization, together with practical considerations such as ease of application and patient safety.

However, parts of the results also showed a need for improvement, such as ease of use and overall suitability, which only one anesthesiologist rated as slightly satisfied without accompanying specific recommendations. The feedback obtained will be considered to refine and optimize the wrist splint design. This interpretation is supported by previous usability research in anesthesia, which has shown that user feedback from prototype evaluation can provide valuable insight for improving device design before wider clinical implementation.¹¹

Additionally, the wrist-splint angles measured in five patients ranged from 30° to 37°, with a median of 33°. These findings were within the range of wrist-extension positions evaluated by Athlani et al.,⁵ who reported that flexor tendon relaxation was maintained at 30° and 45° of wrist extension when metacarpophalangeal joint flexion was maintained. The collected data suggest that the degree of wrist extension varies among individuals. Therefore, the development of a wrist splint with adjustable angulation tailored to each patient’s wrist extension may enhance patient comfort while maintaining wrist stability and supporting continuous arterial blood pressure monitoring.

Evaluating the performance of the wrist splint, particularly in patients with arterial catheterization during surgery is crucial, as arterial lines are commonly used for this purpose, and accurate blood pressure monitoring is significant during operation.¹²

Using the wrist splint showed favorable outcomes in restraining the wrist, reducing the risk of arterial line dislodgement, catheter reinsertion, and improving the accuracy of the blood pressure monitor, further aiding data interpretation.

The medical team expressed satisfaction with the wrist splint, contributing to more efficient and effective patient care during surgery, while maintaining patient safety, and establishing a pattern of effective and continuous blood pressure monitor during surgery.

This study has the following limitations:

1. The sample size of this study is small, which may have contributed to the observed absence of arterial line dislodgement and catheter reinsertion.
2. The primary prototype was designed for functional clinical use, with product design aspects yet to be optimized.
3. The splint is made of cardboard. Once bent into a fixed angle to support the patient’s wrist, the angle cannot be readjusted to precisely fit a specific patient’s arm, potentially leading to instability.

4. The arm and wrist strap may become loose if the patient's arm or wrist is oversized, giving less area for the strap to secure, requiring the area to be secured with tape instead.
5. Since the trial was conducted only while the patient is sedated, it was not possible to evaluate if the securing straps would shift or come loose if the patient regained consciousness and moved.

Researchers recommend having a bigger sample size, a comparison study design (like randomized or controlled before–after studies), and sample size calculation based on the baseline dislodgement rate in the standard practice. To support a more meaningful sample size estimation, future studies should further review the literature on the prevalence of arterial line dislodgement. More bench and usability tests, as well as design changes (like looking at different angles and improved strap systems), may increase the assurance and allow for wider implementation in the clinics.

Conclusion

In this pilot case series, the use of the fixed-wrist splint in patients undergoing intra-arterial catheterization was feasible. No arterial line dislodgement or catheter reinsertion occurred, and continuous arterial blood pressure monitoring

was successfully maintained in all cases. Additionally, anesthesiologists were satisfied with the device, especially regarding safety, practicality, and the benefit of using the fixed-wrist splint.

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Conflicts of Interest

The authors declare no conflicts of interest.

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