現在こうした外傷後ARDSの管理方法については，肺保護戦略に則った人工呼吸管理[22]，間欠的な腹臥位管理[28]，体外式膜型人工肺(extracorporeal membrane oxygenation：ECMO) などが試みられている．ECMOについては，外傷患者への応用は議論のあるところだが，機器や技術の進歩により重症胸部外傷を伴う多発外傷後ARDS患者に導入し，出血や下肢虚血の合併症を増やすことなく，酸素化や循環動態を改善できたと報告されるようになってきた[29]．肺保護戦略に基づいた人工呼吸管理では，低酸素血症が進行するような外傷後ARDS患者では人工呼吸器による二次肺損傷を防ぎ，ガス交換の改善を図るためにECMOの早期導入も“Lung rest”を考慮した治療のオプションとして考えていいのかもしれない．

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Percutaneous Carpal Tunnel Release Compared With Mini-Open Release Using Ultrasonographic Guidance for Both Techniques

Ken-ichi Nakamichi, MD, Shintaro Tachibana, MD, Seizo Yamamoto, MD, Masayoshi Ida, MD

Purpose To compare the outcomes of percutaneous carpal tunnel release (PCTR) and mini-open carpal tunnel release (mini-OCTR) using ultrasonographic guidance for both techniques.

Methods We included 74 hands of 65 women with idiopathic carpal tunnel syndrome (age, 52–71 y; mean, 58 y). Thirty-five hands of 29 women had the PCTR (release with a device consisting of an angled blade, guide, and holder, along a line midway between the median nerve and ulnar artery (safe line) under ultrasonography (incision, 4 mm), and 39 hands of 36 women had the mini-OCTR (release along the safe line, distally under direct vision (incision, 1–1.5 cm) and proximally under ultrasonography, using a device consisting of a basket punch and outer tube.

Results Assessments at 3, 6, 13, 26, 52, and 104 weeks showed no significant differences in neurologic recovery between the groups ($p > .05$). The PCTR group had significantly less pain, greater grip and key-pinch strengths, and better satisfaction scores at 3 and 6 weeks ($p < .05$), and less scar sensitivity at 3, 6, and 13 weeks ($p < .05$). There were no complications.

Conclusions The PCTR provides the same neurologic recovery as does the mini-OCTR. The former leads to less postoperative morbidity and earlier functional return and achievement of satisfaction. *(J Hand Surg 2010;35A:437–445. © 2010 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

Type of study/level of evidence Therapeutic III.

Key words Carpal tunnel release, carpal tunnel syndrome, minimally invasive surgery, mini-open technique, percutaneous technique, ultrasonography.

FOR THE SURGICAL treatment of carpal tunnel syndrome (CTS), 3 options are available: open carpal tunnel release (OCTR), endoscopic carpal tunnel release, and mini-open carpal tunnel release (mini-OCTR).[1,2] The OCTR has been used for a long time and is considered safe and simple, although it is associated with weakness, pillar pain, and a long scar. In an effort to solve these problems, the endoscopic carpal tunnel release was developed. Although it has demonstrated less postoperative morbidity and early return to work and activities of daily living, concerns persist over complications as well as cost. As an alternative to reduce surgical trauma, the mini-OCTR has been proposed. It has closely matched the endoscopic carpal tunnel release in the functional return and decrease in pillar pain, but there still is a concern that part of the procedure is performed blindly.[1,2]

We have used the OCTR (incision from just distal to Kaplan's cardinal line to the wrist crease) for a long

From the Toranomon Hospital, Tokyo, Japan.

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The device in the manuscript was designed by one of the authors (K.N.), patented, and manufactured by Futaba Co., Ltd. (Tokyo, Japan). This author has financial involvement (patent, royalties) with Futaba Co., Ltd.

Corresponding author: Ken-ichi Nakamichi, MD, Department of Orthopaedic Surgery and Rehabilitation Medicine, Toranomon Hospital, 2-2-2, Toranomon, Minato-ku, Tokyo 105-8470, Japan; e-mail: toranomonkajigaya@hotmail.com.

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time and recently the mini-OCTR (incision 1.0–1.5 cm at the distal carpal tunnel) in selected patients. For the latter, we use ultrasonography to protect the critical structures.[3] This provided the same neurologic improvement as the OCTR and better early outcomes regarding pain, scar tenderness, and grip and key-pinch strengths than the OCTR.[3] The difference was attributed to the limited dissection. We then hypothesized that further reduction of surgical trauma could improve the outcome of the mini-OCTR, and we developed a percutaneous carpal tunnel release (PCTR) technique , also using ultrasonography. Although a different ultrasonographically assisted percutaneous release was performed by Rowe et al. in cadavers, to our knowledge, it has not been evaluated clinically.[4] The purpose of this study was to compare the outcomes of the PCTR and mini-OCTR, using ultrasonographic guidance for both techniques.

MATERIALS AND METHODS

Selection of patients

We included 74 hands of 65 women, all homemakers (age, 52–71 y; mean, 58 y), with idiopathic CTS, who were candidates for either of the 2 ultrasonographically assisted carpal tunnel release techniques, the PCTR or mini-OCTR. They initially visited the orthopedic clinic of our institute between November 2001 and March 2007. Two orthopedic surgeons performed the clinical examination. The patients had either thenar muscle weakness or intractable sensory symptoms with poor response to nonsurgical treatment for at least 3 months, including avoidance of overuse, splinting, or local steroid injection. We included this group of patients to provide a uniform model or to eliminate factors related to work and contributory medical conditions.

The diagnosis of CTS was made clinically and electrophysiologically. The clinical evaluation included questioning about sensory symptoms, tests for sensibility and muscle strength, and examination for thenar atrophy. We performed Phalen's test and, if this was negative, reverse Phalen's test (mirror image of Phalen's test). We also checked for Tinel's sign on percussion of the wrist. However, we did not rely solely on these tests to make the diagnosis, considering possible false positive results.

Electrophysiologic studies were performed by 1 examiner in the department of neurophysiology. The criteria for the diagnosis of CTS were a median distal motor nerve latency of greater than 4.2 ms (stimulation, 2 cm proximal to the wrist crease) or a median sensory nerve conduction velocity (between the middle crease of the long finger and 2 cm proximal to the wrist crease) of less than 45 m/s. Patients with findings of a median nerve supplying the hypothenar muscle[5] and an ulnar sensory nerve supplying the third web space[6] were excluded, because these anomalies were contraindications for both techniques.

This study was approved by the internal review board of our institute, and an informed consent was obtained from all the patients before surgery.

Selection of surgical technique

One orthopedic surgeon, who was the most experienced in ultrasonography among the authors, determined the surgical technique for each patient. He obtained axial ultrasonographic images of the carpal tunnel and measured the distance between lines drawn vertical to the transverse carpal ligament (TCL) at the ulnar margin of the median nerve and the radial margin of the ulnar artery. The zone in the TCL between the lines was defined as the *safe zone*.[7]

The mini-OCTR was performed when the safe zone was greater than 3 mm at the proximal carpal tunnel. Unlike the previous report,[7] a distal narrow zone (3 mm or less) was not considered a contraindication because, at the time of distal release, the median nerve and ulnar artery could be protected under direct vision. In contrast, the PCTR was performed when the zone was greater than 3 mm at any level. The PCTR was not performed if ultrasonography showed a hypertrophic flexor pollicis brevis or palmaris brevis[8] extending into the safe zone.

Based on these evaluations, 35 hands (29 women) had the PCTR, and 39 hands (36 women) had the mini-OCTR. The mean age was 56 years (range, 52–71 y) in the PCTR group and 59 years (range, 54–70 y) in the mini-OCTR group. The mean duration of symptoms before surgery was 24 months (range, 4 mo to 20 y) in the former group and 29 months (range, 6 mo to 15 y) in the latter group.

Surgical Technique

PCTR: We used a cutting device consisting of an angled blade (single-use), guide, and holder (Futaba Co., Ltd., Tokyo). A pneumatic tourniquet was not used so that pulsation of the ulnar artery could be recognized. The procedure began with ultrasonographic location of the key structures. In longitudinal images, the TCL and superficial palmar arch (SPA) were identified. In axial images, the median nerve and ulnar artery were located. The entry point was marked on the palm, distal to the critical pillar rectangle,[9] at the intersection of the SPA and a line midway between the ulnar margin of the median nerve and radial margin of the ulnar artery (safe

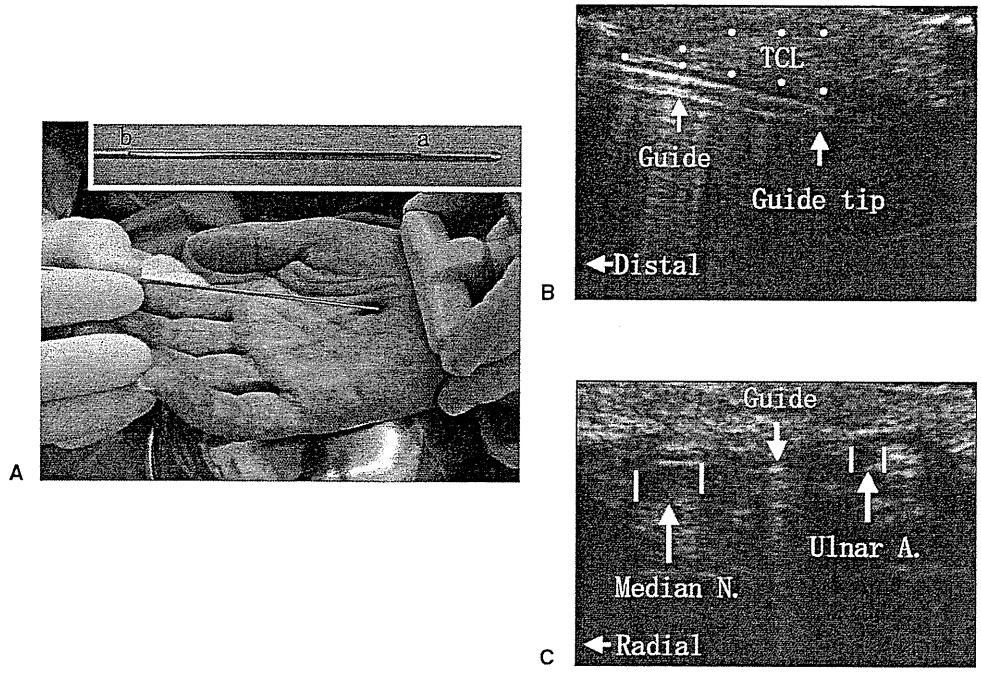

FIGURE 1: Insertion of the guide (14-cm long metal tube, 1.8-mm outer diameter). **A** It is inserted through the palmar aponeurosis, beneath the TCL, from its distal edge along the safe line under ultrasonographic monitoring. The guide has a slot (inset, a–b; 5 cm long, 1 mm wide) on the top, starting 1.5 cm from its tip (to right), to accommodate the blade. It is advanced into the tunnel for 1.5 cm to bring the slot end (inset, a) to the distal edge of the TCL. Proper positioning of the guide is confirmed by biplanar imaging. The guide, under which acoustic shadow is created, is recognized in a sagittal image **B** beneath the TCL (outlined by dots) and in an axial image **C** midway between the ulnar margin of the median nerve (Median N.) and the radial margin of the ulnar artery (Ulnar A.).

line). After administration of local anesthesia, a 4-mm incision was made at the entry point. Under ultrasonographic monitoring, the guide was inserted beneath the TCL, along the safe line (Fig. 1). The cutting device was assembled (Fig. 2). The TCL was divided as the device was advanced proximally, with its tip (blade) localized to the TCL along the safe line, under ultrasonographic monitoring. Release was done to exceed the level proximally, where the enlarged part of the nerve proximal to compression had the largest cross-sectional area, usually 5 to 10 mm proximal to the wrist crease. A single pass of the device completed the release. After device removal, release was confirmed by communication between the inside and the outside of the tunnel with a probe, under palpation or ultrasonography. Because the wound was small, it was not closed.

Mini-OCTR: A pneumatic tourniquet was not used for the same reason as for the PCTR. The distal edge of the TCL and safe line were ultrasonographically recognized and marked on the palm. A 1.0 to 1.5 cm skin incision was designed along the line, with its center crossed by the distal edge of the TCL. After administration of local anesthesia, the incision was made. The distal TCL was divided under direct vision. For proximal release, a device was used that consisted of a basket punch (2.7-mm outer diameter) and an outer metal tube (3.5-mm outer diameter). This was inserted through the incision beneath the TCL in a proximal direction, and the scanner was placed on the palm at the level of the tip of the punch. Under axial imaging, the device was localized along the safe line, and the proximal TCL was divided in a bite-by-bite fashion. The extent of proximal release was the same as in the PCTR. Release was confirmed distally under direct vision and proximally by communication between the inside and the outside of the tunnel with a probe, under palpation or ultrasonography. After irrigation, the wound was closed with monofilament sutures.[3]

Postoperative regimen

No splinting was used in either group. The patients were allowed to use the hand as tolerated. No hand therapy was prescribed. We examined them every 1 or 2 days for wound care and assessment. The wound was defined as healed in the PCTR group when it had complete closure, no discharge, and no separation with the hand opened (full active extension of digits and abduction of the thumb and little finger). In the mini-

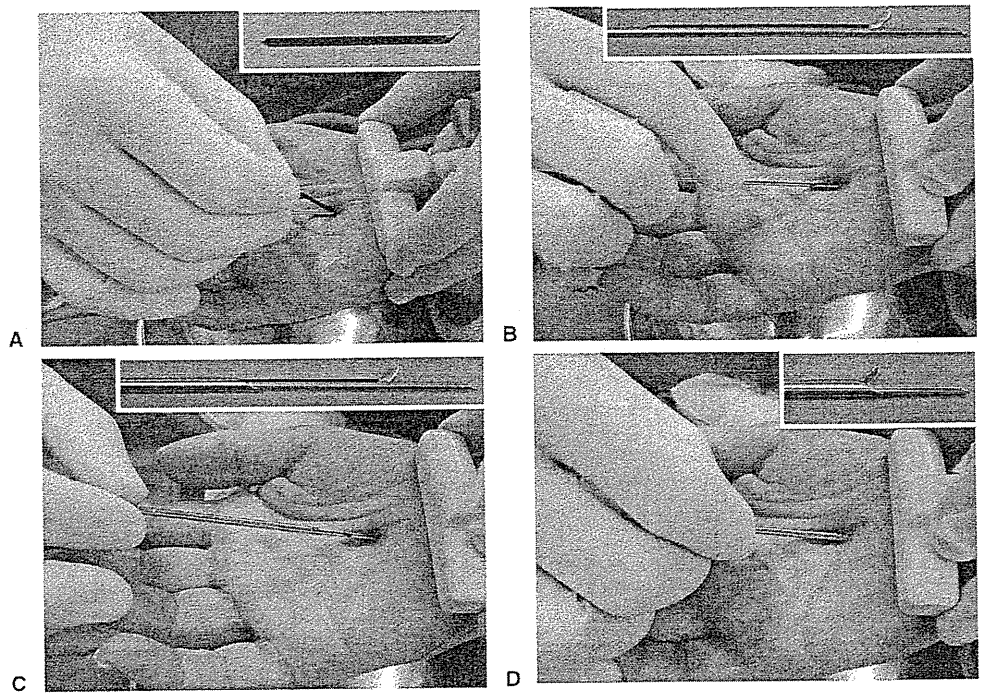

FIGURE 2: Device setup. **A** The cutting edge of a no. 138 blade (inset; 4 cm long, 0.9 mm wide, 4 mm high) is angled parallel to the guide and placed in the slot. Its tip is advanced into the subcutaneous tissue. **B** The blade base is turned downward and placed in the slot (inset). **C** The holder (11 cm long metal tube, 2.5-mm outer diameter) is applied (from left) to hold the blade and guide together (inset). **D** It is advanced to the final position. Inset shows the side view of the assembled device tip.

OCTR group, the sutures were removed 6 to 8 days after surgery, and then the open hand test was done to confirm healing.

Evaluation

The hands were examined before surgery and at 3, 6, 13, 26, 52, and 104 weeks after surgery by a hand therapist who was blinded to the techniques. Before each postoperative examination, the patients attached an adhesive, soft tape to the proximal palm to obscure the incision. All the hands—35 in the PCTR group and 39 in the mini-OCTR group—were evaluated at the initial time interval (before surgery), whereas 29 in the former group and 34 in the latter group were available for the evaluation at the final interval (104 weeks). The numbers of hands evaluated at each time interval are shown in Table 1.

Sensibility was quantified in the long finger by static 2-point discrimination and Semmes-Weinstein monofilament testing. The latter was scored as 1 (normal, 1.65–2.83), 2 (diminished light touch, 3.22–3.61), 3 (diminished protective sensation, 3.84–4.31), or 4 (loss of protective sensation, 4.56–6.65).

Motor tests included manual muscle testing of the abductor pollicis brevis (APB) (results graded 0–5), and grip and key-pinch measurements.

In addition, the following variables were recorded after surgery: pain scored as 0 (absent), 1 (mild, not bothering), 2 (moderate, somewhat bothering but not limiting daily activities), or 3 (severe, bothering and limiting daily activities), time to wound healing, scar sensitivity, and satisfaction (rated from 0 to 5 on a visual analog scale). The scar sensitivity was measured as described by Trumble et al.[10] A pressure meter with a 1.3-cm^2 base (Natume Inc., Tokyo) was applied to the distal, mid, and proximal (wrist crease) carpal tunnel, for 30 seconds at each location, and the lowest load that produced discomfort was recorded. This was also assessed before surgery, with loads of 3.0 kg.[10]

The electrophysiologic studies were performed again just before surgery in those who did not respond to the nonsurgical treatment because their data often became worse. After surgery, the studies were repeated at 13, 26, 52, and 104 weeks.

Statistical analysis

To compare data, we used Student's or Welch's *t*-tests or Mann-Whitney U tests, depending on the data type, normality, and variance. We used analysis of covariance for comparison at each time interval, and repeated-measures analysis of covariance to compare the results of the 2 groups. Hands that were not available for the

TABLE 1. Patient Cohort and Sensory Data

Preoperative Parameters	0 wk	3 wk	6 wk	13 wk	26 wk	52 wk	104 wk
Patient cohort*							
PCTR		35	35	33	33	31	29
Mini-OCTR		39	38	37	35	36	34
Static 2-point discrimination (mm)							
PCTR	11.9 ± 4.7	11.1 ± 4.3	8.9 ± 4.0	6.7 ± 2.9	5.9 ± 2.2	5.7 ± 1.7	5.1 ± 1.3
Mini-OCTR	12.1 ± 4.7	11.5 ± 5.2	10.0 ± 5.7	8.2 ± 4.6	6.7 ± 3.1	6.2 ± 2.8	5.9 ± 2.9
p value	.76	.19	.33	.08	.16	.31	.09
Semmes-Weinstein monofilament grade							
PCTR	3.3 ± 0.6	3.3 ± 0.6	2.9 ± 0.7	2.5 ± 0.7	2.2 ± 0.6	1.9 ± 0.7	1.6 ± 0.5
Mini-OCTR	3.1 ± 0.7	3.1 ± 0.7	3.0 ± 0.9	2.7 ± 0.9	2.3 ± 0.8	2.0 ± 0.7	1.7 ± 60.6
p value	.49	.10	.50	.23	.22	.10	.17

*Patient cohort shows numbers of hands evaluated and applies to all tables.

evaluation were excluded from the analysis. Variables were presented as mean and standard deviation. The reported p values were 2-tailed. The level of significance was $p<.05$. Power analysis (α error, .05; β error, .2) revealed that, with the sample size (35 hands in the PCTR group and 39 hands in the mini-OCTR group), the true difference should be as great as .66 times the standard deviation for continuous variables to detect a significant difference.

RESULTS

Study population

There were no significant differences between the groups with respect to age and duration of symptoms before surgery ($p>.05$ for each variable).

Wound healing

The wound healing time was significantly shorter ($p<.01$) in the PCTR group (mean, 1.4 d; range, 1–4 d) than in the mini-OCTR group (mean, 7.5 d; range, 6–10 d).

Sensory data

The static 2-point discrimination and Semmes-Weinstein monofilament grade are shown in Table 1. After surgery, the sensory variables significantly improved in both groups ($p<.01$ for each variable). There were no significant differences between the groups ($p>.05$ for each variable). The p values for these variables at each time interval are presented in Table 1.

The numbers of symptom-free hands in the PCTR and mini-OCTR groups were 7 (21%) and 10 (27%) at 13 weeks and 26 (90%) and 28 (82%) at 104 weeks, respectively.

Strength

Table 2 shows the APB power, grip strength, and key-pinch strength. Weakness of the APB was noted before surgery in 29 hands in the PCTR group and in 27 hands in the mini-OCTR group. It was graded as 0 before surgery and was not recovered at all at 104 weeks in 5 hands in the former group and in 6 hands in the latter group. The remaining hands showed significant improvement ($p<.01$ in both groups). We found no significant difference between the groups ($p=.59$). The grip and key-pinch strengths decreased significantly at 3 and 6 weeks in both groups ($p<.05$ for each variable). The patients stated that the strengths were limited by the pain. However, they were significantly greater in the PCTR group at 3 weeks ($p<.01$) and 6 weeks ($p<.05$). No significant differences between the groups were seen at later time intervals ($p>.05$). The p values for these variables at each time interval are presented in Table 2.

Pain and scar sensitivity

The pain and scar sensitivity are shown in Table 3. The PCTR group had significantly less pain than the mini-OCTR group at 3 and 6 weeks ($p<.01$ at each time interval). No significant differences between the groups were seen at later time intervals ($p>.05$). At 26 weeks, 3 hands in each of the groups still had mild pain, which was relieved completely by 52 weeks. Before surgery, the scar sensitivity assessment revealed no discomfort with loads of 3.0 kg in both groups. The scars were

TABLE 2. Strength

Preoperative Parameters	0 wk	3 wk	6 wk	13 wk	26 wk	52 wk	104 wk
APB power							
PCTR	2.5 ± 2.0	2.5 ± 2.0	2.8 ± 2.0	3.6 ± 1.7	3.9 ± 1.8	4.1 ± 1.8	4.3 ± 1.8
Mini-OCTR	2.5 ± 2.2	2.7 ± 2.0	3.1 ± 2.2	3.4 ± 2.3	3.6 ± 2.1	4.0 ± 1.8	4.0 ± 1.8
p value	.96	.97	.89	.37	.27	.34	.30
Grip strength (kg)							
PCTR	21.9 ± 3.8	18.2 ± 4.0	20.3 ± 4.2	22.6 ± 4.1	23.7 ± 4.4	24.3 ± 4.3	24.5 ± 4.6
Mini-OCTR	23.7 ± 5.2	15.3 ± 4.0	17.4 ± 4.1	21.7 ± 4.7	25.5 ± 5.6	25.0 ± 5.5	25.1 ± 5.7
p value	.10	<.01	<.01	.13	.33	.96	.99
Key-pinch strength (kg)							
PCTR	3.4 ± 1.2	2.7 ± 1.0	3.0 ± 1.1	3.5 ± 1.1	3.8 ± 1.1	4.0 ± 1.2	4.2 ± 1.2
Mini-OCTR	3.8 ± 1.1	2.4 ± 1.0	2.8 ± 1.1	3.9 ± 1.2	4.2 ± 1.1	4.4 ± 1.1	4.5 ± 1.1
p value	.10	<.01	.04	.78	.64	.48	.34

TABLE 3. Pain, Scar Sensitivity, and Patient Satisfaction

Preoperative Parameters	0 wk	3 wk	6 wk	13 wk	26 wk	52 wk	104 wk
Pain							
PCTR	0.0 ± 0.0	1.4 ± 0.5	0.9 ± 0.4	0.4 ± 0.6	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
Mini-OCTR	0.0 ± 0.0	2.1 ± 0.7	1.4 ± 0.8	0.5 ± 0.7	0.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
p value		<.01	<.01	.45	.89		
Scar sensitivity (kg)							
PCTR	3.0 ± 0.0	1.2 ± 0.4	1.8 ± 0.5	2.3 ± 06	2.7 ± 0.4	3.0 ± 0.0	3.0 ± 0.0
Mini-OCTR	3.0 ± 0.0	1.0 ± 0.4	1.4 ± 0.5	1.8 ± 0.5	2.6 ± 0.4	3.0 ± 0.0	3.0 ± 0.0
p value		.03	<.01	<.01	.15		
Patient satisfaction							
PCTR		3.7 ± 0.4	3.9 ± 0.2	4.3 ± 0.4	4.4 ± 0.5	4.7 ± 0.5	4.8 ± 0.4
Mini-OCTR		3.1 ± 0.3	3.4 ± 0.5	4.1 ± 0.5	4.5 ± 0.5	4.6 ± 0.5	4.7 ± 0.5
p value		<.01	<.01	.24	.62	.47	.36

significantly less sensitive in the PCTR group at 3 weeks ($p=.03$), 6 weeks ($p<.01$), and 13 weeks ($p<.01$). No significant differences between the groups were seen at later time intervals ($p>.05$). The p values for these variables at each time interval are presented in Table 3.

Patient satisfaction

The patient satisfaction is shown in Table 3. The score was significantly better in the PCTR group at 3 and 6 weeks ($p<.01$ at each time interval). No significant differences between the groups were seen at later time intervals ($p>.05$). The p value at each time interval is presented in Table 3.

Electrophysiologic data

Table 4 shows the electrophysiologic results. Motor potentials were undetectable before surgery in 12 hands in the PCTR group and in 16 hands in the mini-OCTR group. It was still undetectable at 104 weeks in 5 hands in the former group and in 6 hands in the latter group. The remaining hands showed significant improvement ($p<.01$ in both groups). Sensory potentials were undetectable before surgery in 19 hands in the PCTR group and in 22 hands in the mini-OCTR group. At 104 weeks, it was still undetectable in 2 hands in the former group and in 1 hand in the latter group. In these hands, motor potentials were also undetectable throughout the course, but there was relief of sensory symptoms. The remaining

TABLE 4. Electrophysiologic Data*

Preoperative Parameters	0 wk	13 wk	26 wk	52 wk	104 wk
Median distal motor latency (ms)					
PCTR	6.3 ± 1.6	4.7 ± 0.7	4.2 ± 0.5	4.0 ± 0.4	3.8 ± 0.4
Mini-OCTR	6.6 ± 1.7	4.8 ± 0.9	4.3 ± 0.7	4.0 ± 0.5	4.0 ± 0.5
p value	.65	.58	.32	.12	.64
Median sensory conduction velocity (m/s)					
PCTR	27.8 ± 6.0	36.0 ± 4.0	38.3 ± 4.2	40.1 ± 4.5	42.3 ± 4.2
Mini-OCTR	27.0 ± 7.7	38.2 ± 4.3	40.5 ± 4.3	43.6 ± 4.5	43.9 ± 4.2
p value	.76	.60	.13	.19	.94

*The hands in which preoperative potentials were undetectable were not included in the statistical analysis.

hands showed significant improvement ($p<.01$ in both groups). We found no significant differences between the groups ($p>.05$ for each variable). The p values for both variables at each time interval are presented in Table 4.

Complications

There were no nerve, vascular, or tendon injuries using either technique. No procedures were converted to the OCTR. Bleeding was minimal. There were no infections. No hands had persistent or recurrent symptoms or signs of complex regional pain syndrome.

DISCUSSION

The PCTR follows the concept of the mini-OCTR: protection of the critical structures under ultrasonography, and it was made less invasive by shortening the incision to 4 mm, placing it out of the critical pillar rectangle,[9] and minimizing dissection. It provided neurologic improvement equal to the mini-OCTR and quicker wound healing, less postoperative morbidity, and earlier functional recovery and achievement of satisfaction than the mini-OCTR. Our previous comparison of the mini-OCTR and OCTR showed similar advantages in the former,[3] and this study indicates that the PCTR has strengthened this trend.

According to the literature, recovery ensues, regardless of the specific technique,[1,2] and this was also the case with ours. However, our patients' improvement seemed slow compared to other series' outcomes. In our series, the percentage of symptom-free hands was less than 30% at 3 months and more than 80% at 2 years. The mean static 2-point discrimination was greater than 10 mm before surgery, and it improved to 6 to 8 mm at 3 months and 5 to 6 mm at 2 years. The mean Semmes-Weinstein monofilament grade showed loss of protective sensation before surgery, which improved to diminished protective sensation at 3 months and diminished light touch at 2 years (Table 1). The mean APB power was <3 before surgery, and reached 4 at 1 year (Table 2). Previous studies[1,2] reported complete symptom relief in 64% to 92% of the patients at 3 months, and 93% to 100% at 6 months. The mean static 2-point discrimination was 6 to 8 mm before surgery and 5 to 6 mm at 3 months. The mean Semmes-Weinstein monofilament grade was diminished protective sensation before surgery, which improved to diminished light touch at 3 months. The mean APB power was >4 before and after surgery. We think that our patients' slower recovery was due to more severe CTS, as shown by the greater 2-point discrimination and Semmes-Weinstein monofilament grade and less APB power before surgery.

The PCTR protects all vital structures. Release along the safe line protects the median nerve and ulnar neurovascular bundle. The position of the latter should be confirmed, because it often exists radial to the hook of hamate.[11,12] The SPA is protected because the device is passed proximal to it. The flexor tendons are mildly retracted by the holder and kept away from the blade. In addition, the device was made thin, minimizing pain and nerve compression.

We also took median nerve anomalies into account. On the basis of Lanz classification,[13] groups II (accessory branches at the distal carpal tunnel) and IV (accessory branches proximal to the tunnel) occur radial to the nerve and are not at risk because release is done ulnarly away from it. Most group I anomalies (variations in the course of the motor branch) are present radial or palmar to the nerve and are not at risk for the same reason. The exception is a branch bent ulnarly at the distal edge of the TCL.[8] This is associated with a

hypertrophic flexor pollicis brevis or palmaris brevis, which can be confirmed by ultrasonography. Unlike the previous report,[3] we now do not consider group III (high division of the nerve) a contraindication, as long as the safe zone is greater than 3 mm.

Although the PCTR minimized surgical trauma, it was still associated with some pillar pain and loss of strengths. Our previous comparison of the mini-OCTR and OCTR showed less pain and better grip and key-pinch strengths in the former,[3] and this comparison of the PCTR and mini-OCTR showed a similar trend. Combining these results and the patients' statement that the pain considerably limited their strengths, we think that the reduction of surgical trauma resulted in less pain and subsequently in better strengths. Although we did not investigate the origin of the pillar pain, we speculate that it is a consequence of transient inflammation, rather than neuromas, for the following reasons: (1) It usually improves in months as the scar softens and the reddish (inflammatory) appearance subsides, and (2) if pain is the result of neuromas from divided nerves, the pain is likely to be more permanent.

Because the carpal tunnel is not explored in the PCTR, we evaluate the following before surgery: (1) Local pathology, including bony abnormalities, space-occupying lesions, and tenosynovial thickening, is ruled out by plain radiographs and ultrasonography. Space-occupying lesions tend to be found in unilaterally afflicted patients.[14] Tenosynovial thickening often indicates inflammation, as in rheumatoid arthritis or infection.[15] (2) Because the device creates an approximately 3-mm-wide acoustic shadow, the safe zone should be wider than this at any level to confirm complete avoidance of the median nerve and ulnar neurovascular bundle.[7] The median nerve enlargement proximal or distal to compression and the ulnar neurovascular bundle radial to the hook of hamate[11,12] narrow the zone. (3) There should be no thick vessels along the path of the cutting device. We screen out the persistent median artery, SPA existing close to the distal TCL, and other vessels by color Doppler imaging. Thick collateral vessels are often found in hands with an arteriovenous fistula for hemodialysis. (4) There should be no hypertrophic flexor pollicis brevis or palmaris brevis extending into the safe zone.[8] (5) Communication is ruled out electrophysiologically between the median nerve and the abductor digiti minimi[5] and between the ulnar nerve and digital nerve to the third web space,[6] because the former crosses and the latter exists close to the safe line. (6) The thickness of the TCL is ultrasonographically measured and should be less than 3 mm. Patients with gigantism sometimes have an extremely thick TCL. Because we designed the cutting device on the basis of the normal anatomy of the TCL,[16] the blade may be small for such patients. However, we have not had this problem with patients of other etiologies. Among these factors, a narrow safe zone constitutes the most frequent reason that the PCTR is contraindicated in our experience.

Although ultrasonography played a major role in this study, its use for carpal tunnel release is not yet an established method. Because it is examiner-dependent, involving a learning curve and interobserver variation in interpretation, the technique should be selected and performed by a surgeon experienced in ultrasonography, as was done in this study. We think that safety is ensured not only by proper performance of surgery but also by correct selection of the technique. Performing a different technique (eg, the PCTR in hands with a distal narrow safe zone) will not necessarily lead to poorer outcomes, as long as release is done without complications, because improvement would ensue regardless of the technique.[1,2] However, this would risk the critical structures.

There are technical tips: (1) The TCL might be deep in a thick hand. If this is the case, pressing the guide dorsally at the entry point will help insertion. (2) The guide should be inserted beneath the TCL from its distal edge. If this is properly done, the resistance upon insertion is minimal. If there is considerable resistance, the guide is likely to be through the TCL, proximal to its distal edge, which would result in distal incomplete release. (3) Release should be completed with a single pass of the device. When division of the proximal TCL is found to be incomplete, it can be divided by repeating the surgical steps (Figs. 1 and 2) without making additional incisions or adding other procedures. In our experience, however, this is time-consuming.

There are limitations to this study: (1) The patients were not randomized to the techniques. We initially attempted randomization. However, this was not possible, primarily because of the variation of the safe zone. Those initially assigned to the PCTR were often found to have a narrow safe zone distally, and the technique had to be converted to the mini-OCTR. Patients' refusal was another reason. Some of them, who had initially been allocated to the mini-OCTR, later wished to have the PCTR. Nevertheless, the preoperative demographic, clinical, and electrophysiologic data from both groups were comparable (Tables 1–4), probably because the study population was homogeneous. (2) No standardized instruments were used for the evaluation. This was because none were available that had been cross-culturally adjusted and authorized to use in our country

during this study period. (3) The sample size was small. To detect a significant difference, the true difference should be greater than .4 times the standard deviation, a conventionally used value,[10] although we confirmed the advantages of the PCTR in the early postoperative period. (4) To test the aforementioned hypothesis, the PCTR was compared with the ultrasonographically assisted mini-OCTR, not with other techniques without ultrasonography, especially the standard mini-OCTR (incision, 1.5–2.0 cm) recently performed by many hand surgeons. However, we think that our mini-OCTR is equivalent to the standard mini-OCTR with respect to the extent of surgical trauma, except for using a slightly shorter incision (1.0–1.5 cm). Therefore, the data on pain, grip and key-pinch strengths, scar sensitivity, and satisfaction scores, as well as neurologic findings, would be similar to those from the standard mini-OCTR.

In summary, the PCTR provided the same neurologic recovery as did the mini-OCTR. It led to quicker wound healing, less postoperative morbidity, and earlier functional return and achievement of satisfaction.

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臨床経験

プロポフォール単剤による救急患者における迅速気管挿管

森本　文雄　　池上　敬一

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臨床経験

プロポフォール単剤による救急患者における迅速気管挿管

森本　文雄　　池上　敬一[1]

【要旨】 方法：プロポフォール単剤による救急患者における迅速気管挿管の状態を，下顎の弛緩，喉頭鏡に対する抵抗，声帯の位置，声帯の動き，チューブ挿入時の刺激による四肢および横隔膜の動きで評価した。結果：22例全例がプロポフォール単剤で気管挿管できた。下顎の弛緩は21例で良好で，喉頭鏡に対する抵抗もなかった。声帯は13例（59%）が開口状態で，動きもなかった。チューブ挿入時の刺激に対して11例(50%)で四肢の動きはなく，10例（45%）で横隔膜の動きもなかった。チューブ挿入時の刺激に対し2例（10%）で四肢は激しく動き，2例（10%）で横隔膜が激しく動いた。うち1例は四肢・横隔膜ともに激しく動いた。気管挿管時の総合評価は，excellent 10例（45%），good 9例（41%），poor 3例（14%）であった。まとめ：プロポフォール単剤で，救急患者における迅速気管挿管可能な状態が作成できる。

索引用語：プロポフォール，迅速気管挿管，鎮静薬

はじめに

迅速気管挿管（RSI；rapid sequence intubation，以下RSIと略す）における薬剤の選択は，施設・医師により使用する薬剤が異なり，標準化が困難な領域といえる。ガイドラインやマニュアルにおいても使用される薬剤の紹介や，いくつかの方法が紹介されるに過ぎない[1,2]。プロポフォールは速効性かつ短時間作働性の鎮静薬で，制吐作用，咽喉頭反射抑制作用，脳保護作用を有し，救急患者に使用するにあたり多くの利点をもつ[3-7]。救急患者においてプロポフォール単剤で迅速気管挿管（RSI；rapid sequence intubation，以下RSIと略す）し，気管挿管時の状態を評価したので報告する。

目　的

プロポフォール単剤での救急患者におけるRSIを評価する。

対象および方法

2001年（平成13年）1月1日から5月31日までに当救命救急センターに自発呼吸を有した状態で来院し，初期治療室で気管挿管が必要となった症例を対象に，気管挿管時の状態を評価した。気管挿管の適応は，意識障害患者（Glasgow coma scale 8点以下で考慮），ショック患者，全身麻酔による処置を必要とする患者，人工呼吸管理を必要とする患者などである。薬物中毒症例，挿管前に抗痙攣薬や筋弛緩薬の投与を受けた例，四肢の動きがない脊髄損傷

Emergency Rapid Sequence Intubation Using Propofol Alone

Fumio MORIMOTO, Keiichi IKEGAMI[1]

Matsudo City Hospital, Department of Trauma and Critical Care Medicine, [1]Dokkyo University School of Medicine, Koshigaya Hospital, Department of Trauma and Critical Care Center

松戸市立病院救急部，[1]獨協医科大学越谷病院救急医療科

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症例は対象から除外した。血圧測定後に末梢静脈路からプロポフォール1-2mg/kg（体重が確認できない場合には主治医が推定）をボーラス投与し，20秒後に睫毛反射の消失と開口が容易なのを確認し気管挿管した。睫毛反射の消失や開口ができない場合，主治医（日本救急医学会指導医2名，日本救急医学会専門医3名）の判断で適宜追加投与し，睫毛反射の消失と開口が可能なのを確認し気管挿管した。気管挿管が30秒以内にできない場合，1度に限りやり直した。やり直し時のプロポフォールの追加投与も，睫毛反射と開口を確認しながら主治医の判断で行った。プロポフォールにより得られる挿管時の状態を，6つの項目（下顎の弛緩，喉頭鏡に対する抵抗，声帯の位置，声帯の動き，チューブ挿入時の刺激に対する四肢および横隔膜の動き）について，最良，良，不可の3段階で評価した[8]（表1）。主治医に加え，各科（外科，麻酔，循環器，整形）からの出向専門医4名からなる担当医と，研修医5名が加わり，チームで気管挿管の状態を評価した。なお声帯の動きを認めた場合には，声帯開口時に気管挿管した。挿管チューブの固定終了後，再度血圧を測定した。6つの項目すべてで最良の場合に，総合評価としてexcellentとした。1項目でも不可がある場合総合評価としてpoorと定義し，ほかはgoodとした。

結　果

5ヶ月間に当救命救急センターに自発呼吸を有した状態で来院し，気管挿管を要した患者は54例(外傷24例，薬物中毒7例，脳血管障害15例，心不全2例，その他6例）であった。薬物中毒7例，挿管前に抗痙攣薬や筋弛緩薬などの投与を受けた15例(外傷4例，脳血管障害7例，その他4例)，四肢の動きがない脊髄損傷2例は除外した。また全身状態が不安定で，挿管時の観察・記録ができなかった8例（外傷7例，心不全1例）を除き，結果として22例（外傷11例，脳血管障害8例，心不全2例，敗血症1例）の気管挿管時の状態を評価した。外傷9例，脳血管障害8例は意識障害で，外傷2例，心不全2例，敗血症1例は人工呼吸管理が必要と判断され気管挿管の適応となった。

プロポフォールを127 ± 55mg使用し，プロポフォールのみで全例気管挿管できた。チューブの挿入は，研修医5名で13例，各科出向専門医4名で6例，日本救急医学会専門医2名で3例行った。喉頭観察中の嘔吐はなかった。

評価の結果を表2に示す。下顎の弛緩が不良の症例はなく，22例中21例で下顎の弛緩は良好であった。また喉頭鏡に対する抵抗も21例でなかった。

声帯は22例中13例（59%）で開口状態であり，動きも静止していた。声帯が閉鎖していた症例はなかったが，9例は半閉鎖状態であった。9例で声帯の動きを認めた。

22例中11例（50%）でチューブ挿入時の刺激に対して四肢の動きはなく，横隔膜の動きも10例（45%）でなかった。チューブ挿入時の刺激に対し2例（10%）で四肢は激しく動き，2例（10%）で横隔膜は激しく動いた。うち1例は四肢・横隔膜ともに激しく動いた。

気管挿管時の総合評価は，excellent 10例（45%），good 9例（41%），poor 3例（14%）であった。

プロポフォール投与前の収縮期血圧は149 ± 44mmHgであったが，挿管後には121 ± 41mmHgに低下した。

考　察

プロポフォール単剤で救急患者22例全例に気管挿管できた。気管挿管時の総合評価は，excellent 10例（45%），good 9例（41%），poor 3例（14%）3例で，理想的な気管挿管の状態とはいえないが，プロポフォール単剤で，救急患者におけるRSI可能な状態が作成できた。

一般的にRSIでは鎮静薬に加え，鎮痛薬，筋弛緩薬が用いられる。患者に応じて薬剤を選択するが，一般的に鎮静薬にはthiopental, midazolamが，鎮痛薬にはfentanylが，筋弛緩剤にはSCC(succinylcholine)，VB（vecuronium bromide）などが用いられる。使用する薬剤は複数となり，注意事項も多い。鎮痛剤であるfentanylは，循環に大きな影響を与えないものの，筋固縮などの副作用をもち，また鎮静薬の多くは循環抑制作用をもつ。筋弛緩薬は，短時間での作用の発現と持続が望ましいものの，これに合致

表1　気管挿管時の状態評価の基準

	評価基準		
	最良	良	不可
下顎の弛緩	良好な弛緩	不完全な弛緩	弛緩不良
喉頭鏡に対する抵抗	なし	少し抵抗	強い抵抗
声帯の位置	開口	半閉鎖	閉鎖
声帯の動き	なし	動いている	閉鎖中
四肢の動き	なし	1・2回の小さな動き	激しい動き
横隔膜の動き	なし	1・2回の小さな動き	激しい動き

表2　気管挿管時の状態評価の結果

	評価基準		
	最良	良	不可
下顎の弛緩	21（95%）	1（5%）	0（0%）
喉頭鏡に対する抵抗	21（95%）	1（5%）	0（0%）
声帯の位置	13（59%）	9（41%）	0（0%）
声帯の動き	13（59%）	9（41%）	0（0%）
四肢の動き	11（50%）	9（40%）	2（10%）
横隔膜の動き	10（45%）	10（45%）	2（10%）

するSCCは，副作用として高カリウム血症，頭蓋内圧上昇，眼圧上昇，胃内圧上昇，投与後の筋肉痛などをもつ。VBは長時間作用する筋弛緩剤で，気管挿管困難時に大きな問題となる。リドカインやアトロピンを前投与する施設もあり，標準化が困難な領域といえる。

近年，筋弛緩薬を使用しない気管挿管が注目されている[9]。麻酔時間の短縮で注目されているが，筋弛緩薬を使用しないことでRSIの2つの大きなリスク（①full stomachの可能性と続発する嘔吐・誤嚥の危険性，②薬剤投与後に認識される予想外の挿管困難）が軽減可能となる。この2つのリスクはとくに救急患者で問題となるが，筋弛緩薬を使用しなければ，胃・食道接合部のflap valve機能が残り嘔吐・誤嚥のリスクが軽減され，予想外の挿管困難時にも自発呼吸があることで対処可能となる。筋弛緩薬を使用すると腹膜刺激症状や，意識レベルの判定が困難になり，時に腹壁筋の弛緩により腹腔内出血が増大する危険性もある。救急患者では数少ない情報で気管挿管しなければならず，筋弛緩薬使用は避けた方が好ましいといえる。また筋弛緩薬は毒薬に分類され麻薬とともに施錠管理が必要である。救急の初期治療室は，絶えず医療従事者が常駐しているわけではなく，また患者・家族の出入りを考慮すると，毒薬・麻薬の保管場所として適切な場所とはいえない。

プロポフォールは劇薬で施錠管理の必要はない。秒単位の急速な効果発現と分単位の効果消失が特徴で，挿管困難時には短時間で挿管前の状態に戻すことができる[3,4]。制吐作用と咽喉頭反射の抑制作用を有し，筋弛緩作用もない[5,6]。したがってプロポフォール単剤によるRSIは，full stomach，挿管困難の2つの大きなリスクを最小限にできる。脳代謝を抑制し，脳保護作用も有し，頭部外傷や脳血管障害患者にも有用である[7]。意識の回復が速やかで，意識レベルの確認が必要な頭部外傷・脳血管障害，中毒患者の鎮静に適している。ただ循環抑制作用があり，血圧低下をきたすため，とくに心不全状態のときは用量を少なく，ゆっくり投与することが必要であろう。またショックをきたしている患者への投与は慎重にするべきである。血管痛を訴える患者もいる。

筋弛緩薬を使用しない気管挿管の報告の多くは，5分前にMidazolam 0.03mg/kgを静脈内投与後，

さらにプロポフォール2mg/kgを加えたり，90秒前にremifentanil2μg/kgやalfentanil20μg/kgを静脈内投与後さらにプロポフォール2mg/kgを加えたりしている[9]。気管壁刺激性低下を目的としたlidocaine1.5mg/kgを前投与する報告もある。これらの薬剤の使用により，理想的な気管挿管時の状態を作成可能なため，プロポフォール単剤での気管挿管を評価した報告はきわめて少ない。刻一刻を争う救急患者でのRSIでは，あらかじめ薬剤を投与することや，さまざまな薬剤を準備することは困難な場合が多い。麻薬や毒薬など施錠管理が難しい初期治療室の特徴も考慮すると，プロポフォール単剤でのRSIは，救急患者において容認できると判断している。意識下挿管（awake intubation）は，胃・食道接合部のflap valve機能や咽頭反射が残存し，誤嚥の可能性が低く救急患者に対する気管挿管として選択枝の1つとなるが，患者の協力が必要で手技に熟練を要する。当センターでは，この研究結果に基づき，その後も年間100－200例のRSIの大部分をプロポフォール単剤で行い，RSIの標準化に成功した。挿管困難から外科的気道確保となった例や，一時的血圧低下をきたした例はあるが，ほかに大きな問題となった例はない。

まとめ

四肢や横隔膜の動きが激しい患者は存在したが，喉頭観察も容易で，観察中の嘔吐もなく，プロポフォール単剤で，救急患者におけるRSI可能な状態が作成できる。

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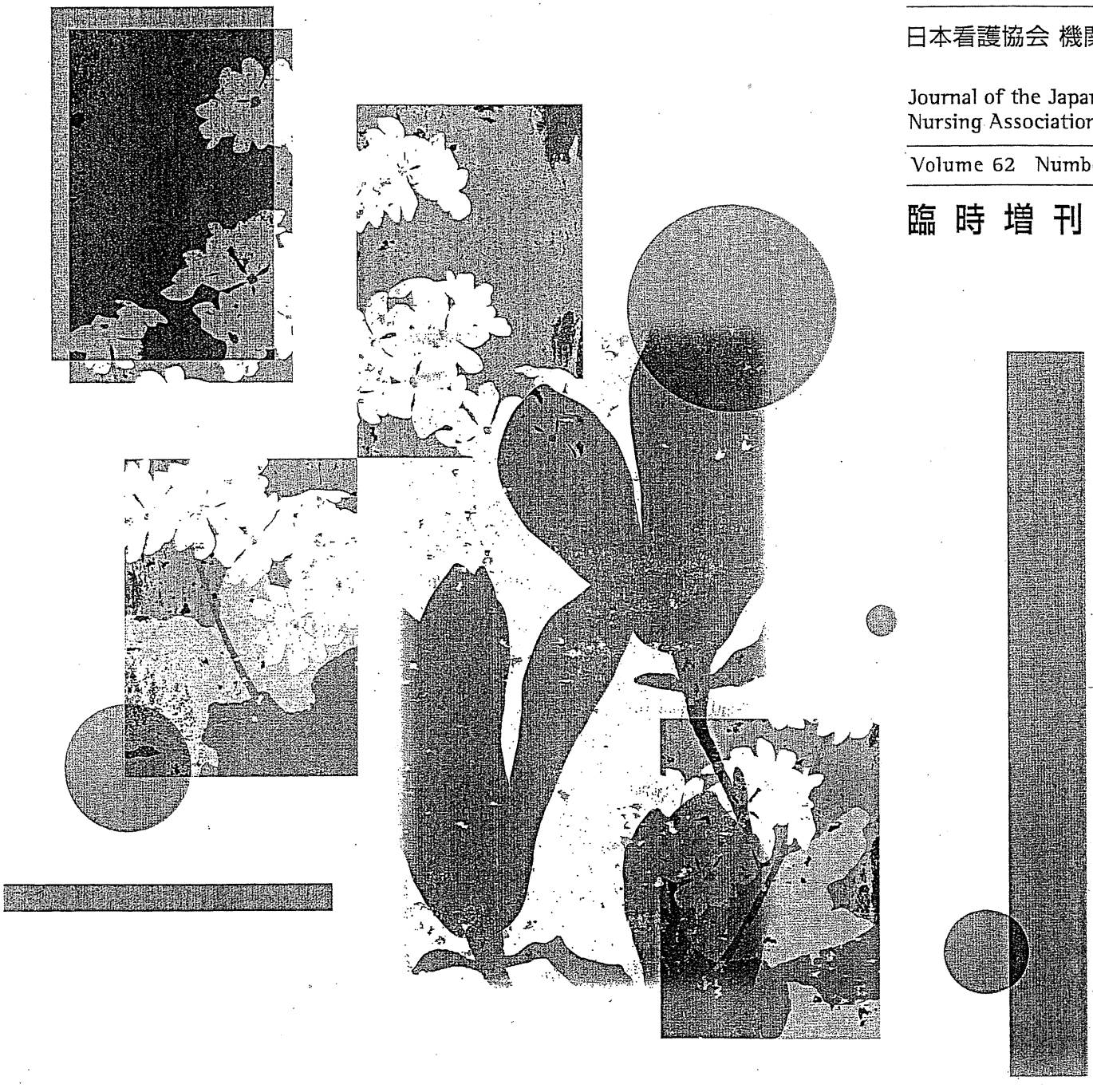

誌面における講師の肩書きは、基本的に講演当時のものを記載しております。
都合により、成人看護I特別講演、看護管理特別講演I、地域看護特別講演の掲載は見送らせていただきました。<編集部>

は多くの時間を要しているのが現状です。また、救急医療や災害医療に対して大きな希望や期待を持って入職してくる看護師の中には、リアリティショックや精神的・身体的ストレスから辞職する者も多く、計画的に教育計画が進められないことも多々あります。

このような中、さまざまな場面において教育を実施するに当たっては、指導的な役割を持つ看護師の育成が重要です。特に初療室など救急の場面においては、優れた知識・技術、アセスメントに基づいた看護実践を率先して行える看護師の存在が、他の看護師のリーダーシップを養うことにつながると考えます。

2008年度より看護師が増員したことによって、初療対応の充実や教育体制の強化を目的に、日中の初療対応看護師を1名から2名に増員しました。今後も机上だけではなく、実際の現場で体験を重ねることができる教育体制を検討していきたいと考えています。

病院内での看護師教育は卒後1～3年目に集中しているため、教育や教育評価などに関し、専門的な教育を受ける機会はほとんどありません。個々の役割やレディネスに応じた研修の機会が得られることで、専門的な教育を受けられるなど、モチベーションを上げられるような関わりが必要であると考えています。

今後、教育的側面においては、看護実践能力を向上させるための教育体制の充実に向け、実践面に重点を置いた教育方法を検討することが重要であると考えています。また、それに伴って指導的な役割を持つ看護師の育成は重要な課題です。

1分1秒を争う救急医療の現場であるからこそ、患者にとって最良の医療が提供できるよう、今後も体制作りや看護師教育に注力していきたいと考えます。

看護師の急性期看護能力を向上する学習システムの開発

池上 敬一

本日は、看護師の急性期看護能力を向上するための学習システムについてお話ししたいと思います。特に「ノン・テクニカルスキル」という言葉を覚えていただきたいと思います。

2009年9月29日に日本医療機能評価機構から発表された1～6月までの医療事故の取りまとめでは、273病院で死亡事故が76件、障害を残す事故が381件起きています。その原因は、「確認を怠った」「判断を誤った」「観察を怠った」「説明が不足していた」「連携ができていなかった」が約60％を占め、「技術・手技が未熟だった」は、4.4％です。

したがって、テクニカルスキルだけが事故の原因ではないことをよく認識しないと、手技の練習をいくら行っても事故は減らないという事実があります。確認、アセスメント、意思決定、観察、説明、連携、チームワークなどは、ノン・テクニカルに関するスキル、つまり日本語で言う「暗黙知」です。

ノン・テクニカルスキルの重要性

現場やエキスパートは当然「暗黙知」を持っていますが、それをどのように教育するのかという方法論がない限り、医療事故はなくならないし、新人看護師は辞めていき、再就職看護師もついてこられない、という悪循環が続くことになります。

航空産業では、飛行機事故のほとんどはノン・テクニカルエラーが原因であるとして、1977年からチームワークの訓練を始めています。しかし、医療の世界に「ノン・テクニカルスキル」という言葉が浸透し始めたのは、最近になってからではないでしょうか。

2009年4月に英国議会が出した「患者安全」報告書の中に、「イギリスの医学教育では“ノン・テクニカルスキル”の重要性の認識、あるいはトレーニングの導入が遅れており、それは容認しがたい段階まで来ている」とあります。また、これからの医療者養成においては、ノン・テクニカルスキルのトレーニングが欠かせないとも提言され、「ノン・テクニカルスキルの

教育を行うことで医療事故は50％減る」という推測がされています。これが世界的な潮流です。

シミュレーションを使った ノン・テクニカルスキルの学習法

これまでの教育での一般的な方法は講義です。しかし、これでチームワークが身に着くでしょうか。仕事に必要な情報をface to faceで教えても、実際には仕事ができないと意味がないので、講義タイプの研修は、特に大人に対しては効果がありません。

今、シミュレーションが非常に脚光を浴びていますが、シミュレーションでは実際の医療場面が再現できるような環境でないと真剣にはなれないでしょう。腕などの部分的なモデルを使って注射の訓練などが行われていますが、欧米ではこれを「シミュレーション」とは呼ばず、「テクニカルスキル・トレーニング」と呼んでいます。日本では、すべて「シミュレーション」と呼んでいるところに誤解があります。ノン・テクニカルスキルのトレーニングは、そのような状況では困難です。ハイクオリティのシミュレーションを行わないと、チーム力を教育することはできません。

ある医学生のブログでは、OSCE（客観的臨床能力試験）の際にシリコン樹脂の“腕”に向かって、「今日は抜糸をさせていただきます」「ちょっと痛いかもしれませんが、我慢してください」と話しかけるなんて、“ばかばかしくてできない”という主張がされていました。これでは学習効果は非常に低くなります。テクニカルスキル・トレーナーでは「態度」の教育はできないのです。

学習者のコンテキストを再現し、学習者が本気になれる環境をつくった中で行うのが「シミュレーション」です。当然、全身モデルを使います。状況が刻々と変化するのが急性期医療の特徴です。それが再現できないと訓練はできません。

では、看護師が行うノン・テクニカルスキルの学習を効果的・効率的・魅力的に促進するには、どうすればよいでしょうか。ポイントは、学習するのは看護師であって、インストラクターやファシリテーターではないことです。まず必要なのは、看護師が「本当に学習したい」と思えるような学習プログラムを提供できることです。それが、看護師が辞めない、また看護師が再就職を望む病院になる一つの条件でしょう。

私たちが開発した「患者急変対応コースfor Nurses」では、ノン・テクニカルスキルのトレーニングに重点を置いています。急変の第一発見者が看護師である状況を設定して、まず、「気づき」のセッションを行い、その後、実際にトレーニングを行います。

その内容は、患者さんを訪室した際に様子が変わっていたので、迅速評価を行った結果、急変を疑い、他の看護師に救急カートを持ってきてもらい、モニターを着けて血圧の測定を行うといった一次評価を行います。その後、1人の看護師が医師に報告し、医師の指示を伝えます。3分間のシミュレーションで、患者さんが死なずに医師に報告でき、医師の指示をその場で実行できれば合格としています。

*

本日の話のまとめとなりますが、まず、救急医療は「チーム医療」の連携であるということ。PA連携もチーム医療であり、PAからER、ICU、後方ベッド、すべて連携であるということです。

そして、チーム医療のポイントはノン・テクニカルスキルであり、その教育にはよく設計された教材が絶対に必要であること。講義ではなく、シミュレーション研修が非常に有効です。全身モデルを使った、プロが本物だと認定できるような環境で行う訓練とファシリテーターの存在が重要になります。

ただし、研修の学びだけでは不十分であり、現場での強化も必要ですので、現場にもファシリテーターが必要になります。これが「ワークプレイスラーニング」という考え方で、今後はこのような考え方が主流になってくると考えられます。

救急の適正利用の推進 —行政の取り組みから—

宮山 徳司

地方自治体が救急医療をどのように認識し、対応し

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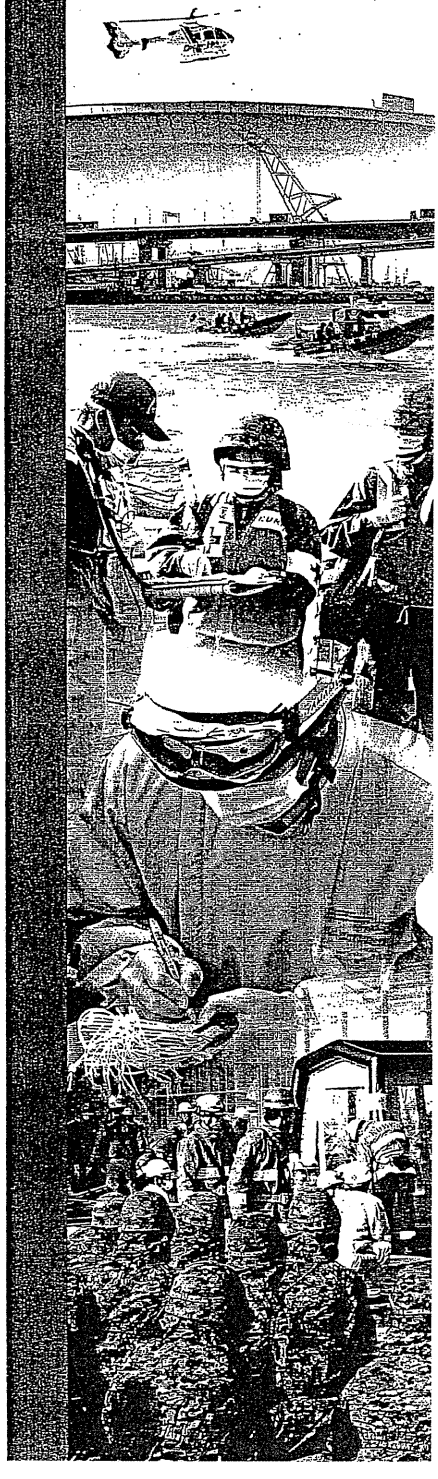

特集

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—ERはコラボレーションの場

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