A new rehabilitation (New-RH) program including respiratory muscle stretch gymnastics (RMSG) was developed to alleviate post-coronary artery bypass grafting pain (PCP). Effects on respiratory muscle function, pain, activities of daily living (ADL), mood and exercise capacity were investigated. Subjects were 16 consecutive patients undergoing median full sternotomy coronary artery bypass grafting (CABG), and were randomly divided into equal New-RH (S-group) and conventional therapy (C-group) groups. Rib cage dominant breathing was observed postoperatively in both groups. With preoperative $\tan \Delta V_r/\Delta V_a$, increases at 1-week postoperatively and decreases at discharge for S-group tended to exceed those of C-group ($p > .05$). Decreased maximum inspiratory and expiratory pressure status for functional residual capacity and percent forced expiratory volume in one second at discharge again only tended to be smaller for S-group ($p > .05$). S-group displayed significantly reduced pain around both scapulas at discharge ($p = .049$), and increased mean overall ADL and profile of mood states (POMS)/Vigor scores ($p = .031$ and $p = .018$, respectively). POMS/Tension-Anxiety scores at discharge for S-group were significantly smaller than those preoperatively ($p = .025$), and S-group displayed significantly increased distance walked over 6-minutes at discharge than C-group ($p = .029$). New-RH improves patient participation in exercise therapy and increases exercise capacity by reducing PCP, relieving anxiety and tension, and improving ADL.

Key words: post coronary artery bypass grafting pain (PCP); respiratory muscle stretch gymnastics (RMSG); Konno-Mead diagram; profile of mood states (POMS); postoperative cardiac rehabilitation

Introduction

Coronary artery bypass grafting (CABG) is a surgical procedure developed during the 1960s for the treatment of coronary artery disease. With recent advances in minimally invasive surgery, CABG is now performed on patients with severe coronary artery disease$^{1-4}$. However, due to the current economic situation surrounding health care, length of hospitalization has been reduced in recent years$^5$. As a result, health care and management for postoperative recovery is currently being reexamined.
One factor that inhibits post-CABG recovery and postoperative cardiac rehabilitation is postoperative chest wall pain or discomfort, which has not been associated with any other cardiac operations. This condition has been reported as internal mammary artery syndrome (IMA syndrome) or post-CABG pain (PCP) since the 1980s, and several studies have been conducted to identify factors involved in the onset and etiology.

As CABG is performed to improve quality of life (QOL) for patients, quick recovery from the invasive surgical procedure is desirable. PCP has been treated by administering analgesics or using transient postoperative relaxation techniques, but more active methods of relieving PCP, such as facilitating recovery of the natural functions of respiratory muscles, have not been investigated.

For some time, PCP has been known to occur in the upper body where the respiratory muscles are located. These respiratory muscles are involved both in functions related to ventilation, such as air pump action, and functions unrelated to ventilation, such as posture maintenance or rolling over. As a result, like the circulatory and skeletal systems, these muscles play very important roles in various human activities.

Therefore, in the present study, as one technique to relieve PCP, we developed postoperative respiratory muscle stretch gymnastics (RMSG). We then investigated the effects on respiratory muscle function, severity of PCP, ease of performing certain ADL, mood state, and exercise capacity.

**Materials and Methods**

1. **The new rehabilitation program incorporating RMSG (Table 1, Figure 1)**
   The RMSG used in the present study were designed to achieve the following: to alleviate PCP caused by surgical procedures or long-term recumbency by relaxing the respiratory muscles; and at the same time, to minimize atrophy of the respiratory muscles and movement limitation, thus facilitating coordinated contraction of the thoracic and abdominal walls and improving the ventilatory and non-ventilatory functions of the respiratory muscles.

   RMSG was originally developed to alleviating exercise-induced respiratory distress in patients with chronic pulmonary disease (CPD). Various types of RMSG exist, and the method of Homma and colleagues, where afferent activities of intercostal muscular spindles are heightened in-phase (during inhalation, the inspiratory intercostals are stretched, while during exhalation, the expiratory intercostals are stretched) has been shown to be effective in alleviating exercise-induced respiratory distress.

   In our previous studies, based on 4 types of RMSG developed by Yamada and colleagues for use on CPD patients, we devised a method consisting of 6 static stretching techniques, excluding abduction and backward stretching of the chest, to avoid dehiscence or vibration of sternal wounds and the onset of PCP. Pretests revealed that the above-mentioned in-phase technique for alleviating respiratory distress would be difficult for CABG patients to perform in the treatment of postoperative pain. As a result, we developed a simpler method to achieve rib cage and systemic muscle relaxation (after individual stretching, relax by taking a deep breath). In addition, since many patients requested exercises that would be effective for alleviating pain around the scapula, we added RMSG-3 (rotating the shoulders, including pectoralis major and trapezius), which was not included in the program by Yamada and colleagues. In addition, in our program, when stretching the serratus anterior, one hand was used to protect the surgical wound to prevent exacerbating PCP. Furthermore, in order for elderly patients to be able to remember and exercise on their own, we limited the number of stretching exercises to five.

   After the patient returned to general ward from the ICU, RMSG was initiated once drainage tubes were removed and patients were allowed to go to the bathroom on their own. S-group patients were instructed to perform RMSG before and after exercise therapy (walking) 3 times a day (morning, noon and night) until discharge.

   The conventional post-CABG rehabilitation program consisted of breathing training (abdominal breathing and pursed lip breathing) and walking exercise, while the new rehabilitation (New-RH) program comprised these exercises and RMSG. In the New-RH program, to deepen subject understanding about PCP, the following points were explained using pamphlets prior to surgery: (1) characteristics of PCP; (2) significance and contents of RMSG; and (3) ADL measures to avoid exacerbating PCP.

2. **Subjects**
   Subjects were 16 consecutive patients who were admitted to undergo median full sternotomy CABG, excluding minimally invasive direct coronary bypass
Table 1. Contents of Respiratory Muscle Stretch Gymnastics (RMSG)

RMSG-1: Whole body relaxation

Either lying down on a bed or sitting in a chair, contract the muscles of the face, shoulder, back, hands and feet for several seconds, then exhale deeply to relax all the muscles of the body.

RMSG-2: Bending the neck forward and to both sides

- Raise shoulders for 5 seconds, then exhale deeply to relax totally.
- While pursing the lips, exhale and bend neck to the right to stretch the sternocleidomastoid, then inhale while bringing neck back to original position. Exhale deeply to relax totally.
- Repeat above procedure, bending neck to the left.

RMSG-3: Rotating the shoulders, including the pectoralis major and trapezius muscles

Gradually rotate shoulders and scapulas forward a few times, then exhale deeply to relax totally.

RMSG-4: Stretching the shoulder girdle and triceps brachii muscle

Extend arms forward as far as possible, and retain this position for 5 seconds. While exhaling, return arms to original positions, and relax totally.

RMSG-5: Stretching the triceps brachii and anterior serratus muscles

- While using one hand to protect the wound, place the other hand on opposite shoulder.
- While inhaling, slowly raise elbow vertically to extend the anterior serratus muscle under the armpit.
- While exhaling deeply, return arm to original position and relax totally.
- Repeat above procedures by changing sides.

Fig. 1. Respiratory muscle stretch gymnastics (RMSG)  *See explanation, Table 1
granting, in the cardiovascular surgery ward of a medical university in Japan between October 2001 and June 2002; were classified as belonging to the low risk group according to the risk assessment system of Tuman and colleagues. In other words, patients with scores of 0-5. This system takes into account 12 risk factors, such as age, left ventricular ejection fraction, renal dysfunction. After ensuring that subjects understood the research information, we obtained voluntary and informed consent in writing. This research protocol was based on the principles enunciated in the Helsinki Declaration. The 16 patients were randomly divided into 2 groups: 8 patients on the New-RH program (S-group), and 8 on the conventional rehabilitation program (C-group). In the present study, patients with current or past history of one of the following conditions were excluded: severe respiratory disorder or disease; severe anemia (hemoglobin < 9.0 g/dl); orthopedic disease with motor dysfunction; psychiatric disease; or other diseases and conditions displaying risk factors such as postoperative mediastinal infection, median sternotomy dehiscence or disruption (severe diabetes mellitus; renal dysfunction on hemodialysis; long-term steroid drug usage; osteoporosis; subnutrition of albumin ≤ 2.5 g/dl; fracture of the sternum, rib or clavicle; paralyzed diaphragm; or severe infection).

Regarding underlying diseases, 13 patients displayed effort-angina pectoris, 10 had old myocardial infarction, 3 had silent myocardial infarction, and 4 had congestive heart failure. Table 2 compares patient profiles between the 2 groups, but no significant differences existed in factors such as risk scores and pulmonary ventilatory functions between the 2 groups, except for preoperative Alb. In addition, no significant differences existed in postoperative pain, intraoperative and postoperative factors associated with mediastinitis and median sternotomy dehiscence (postoperative albumin, total operation and cardiopulmonary bypass times, duration of mechanical ventilation in the ICU, etc.) and postoperative exercise capacity between the 2 groups. Furthermore, no significant difference existed between the 2 groups in the number of postoperative days before drainage tubes were removed or before patients began to walk (S-group: 4.75 ± 0.71 days, C-group: 4.5 ± 0.76 days, p > .05).

Harvesting the internal mammary artery (IMA) is a contributing factor for postoperative mediastinitis, and in the present study, skeletonization was used to harvest the IMA in all cases. In addition, laparotomy was performed by extending the median sternal incision about 5 cm only when harvesting the right gastroepiploic artery (GEA).

In all patients, including those in C-group, no severe complications such as mediastinitis or median sternotomy dehiscence were observed up to 3 months after surgery.

3. Methods

1) Respiratory function tests

(1) Pulmonary ventilatory functions

To assess pulmonary ventilatory functions, percent vital capacity (VC) and percent forced expiratory volume in one second (FEV1.0%) were measured prior to surgery and at discharge using an electronic spirometer (FUDAC 50, Fukuda DENSHI K.K., Japan).

(2) Respiratory muscle pressure

Respiratory muscle pressure was assessed by measuring maximum inspiratory pressure status at the level of functional residual capacity (FRC) (MIPS (FRC)) and maximum expiratory pressure status at the level of FRC (MEPS (FRC) ) according to the intraoral pressure method using a respiratory muscle dynamometer (Vitalopower KH-101, CHEST K.K., Japan). These measurements were taken at least 3 times prior to surgery and at discharge, and the most favorable results were used.

(3) Breathing patterns (Figure 2, Table 3)

Breathing patterns were assessed by measuring thoracic and abdominal movements using inductive respiratory bands (CHEST K.K., Japan) and Konno-Mead (K-M) diagrams introduced by Konno and colleagues in 1967. While in the resting standing posture, breathing patterns were assessed prior to surgery, 7 days after surgery (by this time, the general condition of the patients was stable, and every patient was able to walk) and at discharge.

The thoracic band was positioned at the nipple level, while the abdominal band was positioned at the level of the umbilicus. In all subjects, length of the bands was adjusted to suit each body type to ensure that they were wrapped tightly around the body. When assessing breathing patterns postoperatively, bands were put in place only after first protecting surgical wounds using clean gauze.

By simultaneously measuring resting tidal volume (TV) using an electronic spirometer (Chestgraph Jr. H-101, CHEST K.K., Japan), thoracic and abdominal movements were converted into costal wall volume change (ΔVrc) and abdominal wall volume change (ΔVab) and then recorded using an X-Y recorder (WR8500 4LCD type, GRAPHTEC K.K., Japan).
Regarding breathing patterns assessed using respiratory bands, Yonezawa classified breathing into 4 patterns based on Vrc/Vab ratios as follows: normal breathing (N pattern), rib cage dominant breathing (R pattern), abdomen dominant breathing (A pattern), and paradoxical breathing (P pattern). In the present study, breathing patterns were assessed according to the judgment criteria established by Kawagoe, where breathing patterns are determined based on the Vrc/Vab ratio and the line connecting FRC and end-inspiratory pause (EIP).

2) Exercise capacity

To assess exercise capacity, a 6-minute distance walk test (6MWD) was performed just before discharge, and walking distance, 10-grade Borg Score, pressure rate product (PRP: reflects myocardial oxygen consumption and is calculated by multiplying heart rate by systolic blood pressure), arterial oxygen saturation (SpO2) using a pulse oxymeter (Pulsox-3i, MINOLTA K.K., Japan) and electrocardiographic findings were measured.

The 6MWD test is an inexpensive and highly safe exercise tolerance test introduced by Guyatt and colleagues in 1985, and its reproducibility has been shown to be stable (6MWD correlates to both the NYHA classification and Specific Activity Scale). However, 6MWD is likely to be influenced by such factors as repeated tests and patient volition, and as a result, in the present study, 6MWD was administered according to conventional methods by considering the following 3 points: (1) encouraging words were given every 30 s; (2) the patient was informed of test time every 2 minutes; and (3) the patient was observed from behind, not by walking beside the patient. The 6MWD test was administered twice with a 15-minute break.
between tests, and the longest distance achieved in the 2 tests was used. In addition, the Borg Score\(^{43}\) is a quantitative indicator of perceived exertion with a high degree of reproducibility, and closely correlates to heart rate and oxygen consumption during exercise.

3) Location and severity of post-CABG pain

Location and severity of PCP were assessed 7 days after surgery and at discharge. The location of PCP was determined by asking each patient to indicate where he or she felt PCP, and then we recorded the location of PCP using the pictures shown in Figure 3. Severity of pain was subjectively assessed using a numerical rating scale, where a score of 0 indicated “no pain”, a score of 2 “slight pain”, a score of 4 “mild pain and mildly difficult to bear”, a score of 6 “moderate pain and difficult to bear”, a score of 8 “severe pain and very difficult to bear”, and a score of 10 “unbearably severe pain”. In addition, usage of analgesics and cold compresses was recorded in medical charts.

4) Activities of daily living (ADL)

ADL was assessed 7 days after surgery and at discharge.
charge by assessing the ease of performing the following 6 upper body activities that most patients often perform while hospitalized: putting on and taking off underwear (“underwear”), putting on and taking off trousers (“trousers”), shampooing (“shampoo”), washing the back (“back”), lying down on the bed (“lying down”), and getting up from the bed (“getting up”). The ease of performing these activities was assessed using 10-grade visual analogue scales (VAS), where a score of 0 indicated “very easy”, a score of 2 “easy”, a score of 4 “slightly difficult”, a score of 6 “difficult”, a score of 8 “very difficult”, and a score of 10 “impossible”.

5) Emotions and moods

Emotions and moods were assessed prior to surgery and at discharge using the Japanese version of the Profile of Mood States (POMS)44-46. This scale was developed in America by McNair and colleagues in 1964 to subjectively assess the moods and emotions of test subjects, and comprises 65 questions dealing with the following 6 categories: tension-anxiety (T-A), depression-dejection (D), anger-hostility (A-H), vigor (V), fatigue (F), and confusion (C). Of the 65 questions, 7 are dummy questions, and test subjects answer each question by choosing from the following 5 options: 0 = “not at all”, 1 = “slightly unlike this”, 2 = “slightly like this”, 3 = “much like this”, and 4 = “extremely”. For each category, scores are added for quantitative assessments. Except for vigor, the higher the score, the more severe the mood, such as anxiety and depression. With vigor, a higher score indicated increased vigor.

Although POMS was originally developed to assess mood states over the preceding week, because this time reference can be changed, subjects in the present study were asked to assess current mood states.

4. Statistical analysis

A paired-sample t-test was used to compare data collected prior to surgery, 7 days after surgery and at discharge. In addition, when comparing data between the 2 groups, after confirming homogeneity using a Levene test, a t-test was performed. Wilcoxon rank sum and exact tests were used to compare relative changes prior to surgery, 7 days after surgery and at discharge between the 2 groups. These analyses were performed using Dr. SPSS II for Windows, and the level of statistical significance was set at < 5%.

Results

1. Breathing patterns (Figure 4)

Figure 4-a shows the EIP for the 16 patients prior to surgery, 7 days after surgery and at discharge in a K-M diagram, while Figure 4-b shows changes in tan\Delta Vrc/\Delta Vab. Although the degree of fluctuation in EIP for C-group was greater than that for S-group, TV decreased significantly 7 days after surgery in both groups (C-group p = .023; S-group p = .004), confirming a shift to the R breathing pattern. The results of a paired sample t-test on tan\Delta Vrc/\Delta Vab showed that, for C-group only, when compared to the mean tan\Delta Vrc/\Delta Vab prior to surgery, the value increased significantly 7 days after surgery (p = .026) and then decreased significantly at discharge (p = .037). Figure 4-c shows relative changes in tan\Delta Vrc/\Delta Vab in relation to the preoperative mean. When compared to C-group, the degree of increase 7 days after surgery and the degree of decrease at discharge for S-group were greater, but no significant differences were observed between the 2 groups. Also, for both groups, levels of TV and tan\Delta Vrc/\Delta Vab at discharge were comparable to levels of these parameters prior to surgery.

Regarding the relationship between breathing patterns and the location and severity of pain in each subject, the ratio of patients with R breathing patterns was high among 7 patients who had pain scores of 8 or above (“very painful” and more severe) in the ant-4 region.

2. Respiratory functions and exercise capacity (Figure 5)

The 6MWD at discharge for the S-group was 560 \(\pm\) 73 m, while that for the C-group was 466 \(\pm\) 82 m, and a significant difference existed between the 2 groups (p = .029). However, no significant differences in Borg Score (respiratory sensation), PRP and SpO2. Furthermore, in all patients, ECG performed after the 6MWD test demonstrated no findings indicative of ischemia.

For both groups, mean MIPS (FRC) at discharge was significantly lower than that prior to surgery (C-group: preoperative 60.7 \(\pm\) 23.3 cmH2O, at discharge 45.4 \(\pm\) 17.3 cmH2O, p = .016; S-group: preoperative 67.6 \(\pm\) 24.8 cmH2O, at discharge 56.5 \(\pm\) 18.4 cmH2O, p = .013). There were no significant differences between the 2 groups. Figure 5 shows relative changes in this parameter in relation to the preoperative value. Although the degree of decrease for S-group was lower, no significant difference existed between the...
2 groups. The degree of change in mean MEPS (FRC) was comparable to that for MIPS (FRC): (C-group: preoperative 68.4 ± 25.5 cmH₂O, at discharge 52.6 ± 18.1 cmH₂O, p = .002; S-group: preoperative 75.1 ± 25.3 cmH₂O, at discharge 63.8 ± 24.5 cmH₂O, p = .041).

For C-group, %VC at discharge was significantly lower than that prior to surgery (preoperative 100.7 ± 14.4, at discharge 83.5 ± 10.0, p = .004). Similarly, S-group, displayed significantly lower %VC than that prior to surgery (preoperative 112.9 ± 18.2, at discharge 89.6 ± 13.9, p < .001). However, no significant differences in mean values or relative changes were observed between the 2 groups. Moreover, S-group demonstrated a significant improvement in FEV₁₀₀% (preoperative 77.5 ± 6.5, at discharge 79.5 ± 5.6, p =
but no significant differences in mean values or relative changes between the 2 groups.

3. PCP, ADL and mood states (Table 4)

Regarding the breakdown of the location of pain, subjects experienced pains in the ant-1, 2, 3 or 4 region or in the post-2 or 3 region. As shown in Table 4, location of PCP could be classified into 4 regions: “ant-1”, “ant-2,3”, “ant-4” and "post-2,3". For both groups, severity of PCP 7 days after surgery was significantly higher than that at discharge, and a significant difference was seen in the severity of PCP in the post-2,3 region between the 2 groups (C-group, 2.4 ± 2.1; S-group, 0.6 ± 0.9, p = .049).

To alleviate PCP, some subjects used non-steroidal anti-inflammatory agents or cold compresses. Five patients took non-steroidal anti-inflammatory agents (3 C-group patients, and 2 S-group patients), and these patients displayed PCP with scores of 8 ("very painful") and above in the ant-1 or ant-4 region. Also, 6 patients used cold compresses (4 C-group patients, and 2 S-group patients), and these patients had severe PCP scores in the post-2,3 region. As to the relationship between graft harvesting and PCP location, 6 of 9 GEA cases complained of severe pain in the ant-4 region.

For ADL, significant improvements were seen for all activities in all patients at discharge when compared to those 7 days after surgery. There were significant differences in the following 3 activities between the 2 groups: “trousers” (C-group, 0.9 ± 1.0; S-group, 0.0 ± 0.0, p = .041), “shampoo” (C-group, 2.1 ± 1.4; S-group, 0.5 ± 1.1, p = 0.019) and “getting up” (C-group, 2.3 ± 1.6; S-group, 0.4 ± 0.7, p = .013). Also, overall mean at discharge for S-group (3.6 ± 4.3) was significantly lower than that for C-group (10.5 ± 6.8, p = .031). As to the relationship between ADL and the location of PCP at discharge, the ratio of patients who displayed difficulty shampooing (score: ≥ 4) was high among C-group patients who had moderate and severe pain with a score of 4 and above in the intercostal (ant-2,3) region.

With regard to POMS, the T-A score at discharge for S-group (8.8 ± 2.1) was significantly lower than that prior to surgery (12.9 ± 3.9, p = .025). Also, V score at discharge for S-group was significantly higher than that for C-group (19.0 ± 4.5 and 14.1 ± 2.5, respectively, p = .018).
Table 4. Comparison of changes in PCP level, ADL score and POMS score between the two group

<table>
<thead>
<tr>
<th></th>
<th>C-group (n=8)</th>
<th>S-group (n=8)</th>
<th>$p$ values by $t$ test</th>
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<td></td>
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<td>Dis 1.4 **</td>
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<td></td>
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<td>Dis 1.5 **</td>
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<td></td>
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</table>

* $p<.05$, ** $p<.01$, *** $p<.001$, ns = not significant (by paired-sample t test)

Pre: preoperative-day data, PO7: data at postoperative-day-7, Dis: data just before discharge
ant-1,2,3,4, post-2,3; see the picture of Figure 3
ADL: activities of daily living
underwear: putting on and taking off underwear, trousers: putting on and taking off trousers
shampoo: shampooing, back: washing the back, lying down: lying down on the bed
getting up: getting up from the bed
POMS: Profile of Mood States
C: Confusion
Discussion

1. Effects of RMSG on respiratory functions

PCP persists for several months after surgery, and differs from preoperative pain caused by cardiac ischemia because PCP is caused by such factors as incisional pain from the median sternal wound; painful paresthesia around the wound; musculoskeletal nociception caused by surgical procedures such as retractor usage and IMA harvesting; or epigastric area pain caused by mediastinal and chest tubes. The major causes of intercostal pain are rib fractures caused by retractor usage or surgical procedures; painful sternal wires; and sternal infection.6-16 Subjects in the present study experienced PCP in the following 4 regions: median sternal wound (ant-1), bilateral intercostals (ant-2,3), drainage removal and upper abdominal wound (epigastrium, ant-4), and around the scapulas (post-2,3). In addition, with breathing patterns, paradoxical breathing (P pattern) was not seen in any subject. This was probably due to the fact that patients with suspected clavicle or rib fracture on postoperative chest radiographs were excluded, but P breathing pattern and upper arm, shoulder and neck pains could have been seen if compression from retractor usage had caused clavicle or rib fracture.

This time, no significant differences in breathing patterns were observed between the 2 groups, and for both groups, rib cage dominant breathing was confirmed 7 days after surgery. However, along with physical recovery, breathing patterns also normalized. Seven patients who had severe pain in the ant-4 region 7 days after surgery exhibited R breathing patterns. This agrees with Gordon and colleagues’ 1983 report in which chronological shifts in K-M diagrams were investigated in patients who underwent upper abdominal surgery. In other words, due to rib cage distortion (restricted degree of freedom for breathing) caused by various surgical procedures, accessory respiratory muscles such as the sternocleidomastoid and superior intercostals become active, resulting in rib cage dominant breathing.

In the present study, no statistically significant differences in the degree of change in tan ΔVrc/ΔVab, MIPS (FRC), MEPS (FRC), %VC and FEV₁,₀% were present between the 2 groups. As shown in Figure 4-c, although the degree of increase in tan ΔVrc/ΔVab 7 days after surgery for S-group was greater than that for C-group, the degree of decrease in tan ΔVrc/ΔVab at discharge was greater for S-group, suggesting that recovery was quicker for S-group patients, who were subjected to more invasive surgical procedures in the chest wall. The severity of surgical invasion to the chest wall correlates to the extent and angle of surgical procedures, such as retractor-based thoracotomy, but the present study assessed surgical invasiveness by analyzing only surgery time, anesthesia time, duration of mechanical ventilation, and number of internal thoracic arteries involved. As low invasive surgery is performed more frequently, clarifying the degree of invasion to the respiratory muscles represents important clinical data for improving patient QOL.

Likewise, the degrees of decrease in MIPS (FRC) and MEPS (FRC) at discharge for S-group were lower than those for C-group, and changes in FEV₁,₀% showed improvements (Figure 5), suggesting that RMSG somehow influenced postoperative distortion and pulmonary ventilatory functions. The reasons for failing to see statistically significant differences in the present study include the short postoperative stay (average: 24.4 days) and the small subject population (16 patients). In the future, verification of the long-term effects of the New-RH program by following patients after discharge will be necessary.

2. Effects of RMSG on PCP

Our RMSG was shown to be effective in relieving PCP in the post-2,3 (around scapulas) region, as a significant difference in the severity of pain was observed between the 2 groups. Cold compresses were applied predominantly to this region. Muscular tension around the scapulas could be induced by factors such as long-term recumbency in the supine position, compression of the costovertebral joints by a retractor, and paravertebral muscle contracture. The present RMSG, incorporating relaxation, was able to alleviate PCP by facilitating muscular extension and relaxation and increasing the degree of freedom for movements.

All 5 patients who underwent single administration of non-steroidal anti-inflammatory agents (no significant difference existed in number of internal uses between the 2 groups) displayed either median sternal wound pain (ant-1) or upper abdominal incisional pain (ant-4), thus suggesting that analgesics are more effective than RMSG in relieving inflammatory pains in peripheral tissues caused by invasive stimuli.

Moreover, effectiveness of the present RMSG for relieving intercostal pain (ant-2,3) could not be clarified by the present study. When a patient experiences intercostal pain, it is necessary to first check for clavicular or costal fracture, and if a fracture is found, the adminis-
traction of analgesics and immobilization of the rib cage are important for preventing flail chest, pneumothorax and hemothorax. Even if a fracture is not found, because uncomfortable sensation persists for a few months\textsuperscript{12-14}, further investigations are needed on surgical procedures, thoracotomy techniques, appropriate pain alleviation techniques and long-term RMSG.

3. Effects of RMSG on PCP, ADL and moods

In the present study, in terms of the ease of performing certain ADL at discharge, significant differences existed between C-group and S-group in the following 3 activities: putting on and taking off trousers, shampooing, and getting up from the bed. With regard to putting on and taking off trousers, because the saphenous vein graft was not harvested in any of the S-group patients, leg incisional pain was not an issue in any patients. As to getting up from the bed, the significant difference between the 2 groups was probably not attributable to the RMSG itself, but to the fact the New-RH program included preoperative explanation and training about lying down on the bed and getting up from the bed to avoid exacerbating PCP. Shampooing requires less upper arm extension than washing the back, but the ratio of patients who had a difficult time shampooing was high among C-group patients with moderate pain in the ant-2,3 (intercostal) region. This suggests that intercostal pain following CABG could hinder ADL the most. Furthermore, in terms of POMS, the T-A (tension and anxiety) score at discharge for S-group was significantly lower than that prior surgery, but the T-A score at discharge for C-group was higher than that prior surgery. Also, the V (vigor) score at discharge for S-group was significantly higher than that for C-group. These findings suggest that not being able to perform ADL such as shampooing after surgery increases anxiety and stress levels and lowers vigor. The above-mentioned significant differences could have been attributed to the fact that the New-RH program included explanations about the characteristics and causes of PCP and ADL measures to alleviate postoperative pain. Several studies have documented the importance of educational programs\textsuperscript{49,50}, and as a result, in order to achieve favorable postoperative recovery and facilitate patient participation, it appears important for patients to be informed about PCP.

4. Effects of RMSG on PCP and exercise capacity

This time, 6MWD was measured to assess the exercise capacity of subjects. This test is safe, convenient and inexpensive, but test results are easily influenced by patient motivation. In the present study, 6MWD for S-group was significantly greater, but since the T-A (tension and anxiety) score at discharge for S-group was significantly lower than that prior to surgery and the V (vigor) score for S-group was significantly higher than that for C-group, walking distance could have been influenced by the severity of pain, the ease of performing ADL, and mood states. The results of past studies have shown that severity of postoperative pain, physical and living functions, and psychological states appear to play very important roles in determining the degree to which patients become actively involved in postoperative recovery\textsuperscript{17,18,51}

Also, although the 6MWD for S-group was significantly greater than that for C-group, no significant differences in Borg Scores or PRP were observed. This suggests that the RMSG indirectly influenced exercise capacity. In the present study, the effects of RMSG on breathing patterns, respiratory muscle pressure and pulmonary ventilatory functions could not be verified, but because post-CABG patients are in a state of transient and mechanical restrictive impairment due to upper body wound pains and muscle aches, RMSG incorporating breathing and relaxation techniques could have alleviated exercise-induced imbalance in increased pulmonary ventilation to lower the threshold for respiratory sensation (respiratory distress), thus indirectly increasing 6MWD.

In any case, with studying more patients, it will be necessary to investigate the relationship between chronological changes in postoperative breathing patterns and the location and severity of pain, and the relationship between RMSG and factors such as respiratory muscle pressure, pulmonary ventilatory functions and exercise capacity using more reliable tests such as expired gas assay.

The New-RH program (conventional exercise therapy combined with our RMSG) included explanations about the significance and contents of RMSG, the characteristics of PCP, and ADL measures to avoid exacerbating PCP. This could have contributed to favorable mood states, ADL and 6MWD. In future, the development of more desirable pain management techniques or exercises will be important, by further investigating the above issues and gender and age differences.

Conclusions

In the present study, patients who were scheduled to
undergo median full sternotomy CABG were placed on a new rehabilitation program, consisting of conventional exercise therapy, our RMSG and an informative session about the characteristics of PCP and ADL measures to prevent exacerbation of PCP.

The results showed that this new rehabilitation program was useful in alleviating muscle aches around the scapula; reducing tension and anxiety at discharge; and improving the ease of performing certain ADL, ultimately improving patient participation in exercise therapy and increasing exercise capacity. Although the effects of this new rehabilitation program on breathing patterns, respiratory muscle pressure and pulmonary ventilatory functions could not be verified by the present study, these issues need to be investigated further by analyzing RMSG and test methods, increasing the number of subjects, and lengthening the study period.

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References


