Supported Arm Training in Patients Recently Weaned From Mechanical Ventilation*

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Study objectives: To evaluate the effects of early exercise training in patients recovering from acute respiratory failure needing mechanical ventilation (MV).

Design: Prospective, randomized, and controlled study.

Setting: Three respiratory intermediate ICUs (RIICUs).

Patients: Of 228 patients admitted to an RIICU, 66 patients weaned from MV from > 48 to < 96 h were considered eligible and enrolled in the study.

Intervention: Sixty-six patients were randomized to either supported arm exercise training plus general physiotherapy (gPT) [group 1, 32 patients] or to gPT alone (group 2, 34 patients).

Measurements and results: Twenty-five patients in each group completed the protocol. Group 1 showed a greater improvement in exercise capacity, as assessed by an arm incremental test (IT) \( p = 0.003 \) and an endurance test (ET) \( p = 0.021 \), compared to group 2. Posttraining maximal inspiratory pressure (MIP) significantly improved in both groups \( p < 0.001 \) and \( p = 0.003 \) in groups 1 and 2 respectively; not significant). IT isoworkload dyspnea improved significantly in both groups \( p = 0.005 \) and \( p = 0.009 \) in groups 1 and 2, respectively; not significant between groups, whereas IT isoworkload peripheral muscle fatigue \( p < 0.001 \), ET isotime dyspnea \( < 0.01 \), and ET isotime muscular fatigue \( p < 0.005 \) improved significantly in group 1 but not in group 2. IT improvers \( \chi^2 = 0.004 \) and ET improvers \( \chi^2 = 0.047 \) were more frequently observed in group 1 than in group 2. Baseline MIP could discriminate for IT \( p = 0.013 \); odds ratio [OR], 1.116) and ET improvers \( p = 0.022 \); OR, 1.067).

Conclusion: Early upper-limb exercise training is feasible in RIICU patients recently weaned from MV and can enhance the effects of gPT. Baseline inspiratory muscle function is related to exercise capacity improvement.

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Key words: exercise therapy; rehabilitation; respiratory insufficiency; respiratory intermediate ICUs; weaning

Abbreviations: ARF = acute respiratory failure; BMI = body mass index; CI = confidence interval; ET = endurance test; \( FIO_2 \) = fraction of inspired oxygen; gPT = general physiotherapy; IT = incremental test; MIP = maximal inspiratory pressure; MV = mechanical ventilation; OR = odds ratio; PRP = pulmonary rehabilitation program; RIICU = respiratory intermediate ICU; SAEx = supported arm exercise training

Rehabilitation for patients with respiratory diseases is well established and widely accepted as a means of alleviating symptoms and optimizing function, independent of disease stage.1 Randomized controlled studies,2–5 as well as metaanalyses6 have shown that intensive, multidisciplinary, inpatient and outpatient pulmonary rehabilitation programs (PRPs) focused on lower-extremity exercise7 are an effective intervention in the short term and long term for patients with stable COPD. Fewer studies8–11 have been specifically dedicated to arm exercise, although COPD patients report disabling dyspnea for daily activities involving the upper extremities at work levels. Even less is known about the effectiveness of a PRP in patients undergoing acute exacerbations of their disease, namely patients requiring ICU admission and needing mechanical ventilation (MV). In a group of COPD patients
admitted to a respiratory intermediate ICU (RIICU), Zanotti et al\textsuperscript{12} showed positive effects of electrical stimulation on peripheral muscles strength and a reduction in the number of days needed to transfer from bed to chair. In the only prospective, controlled, randomized study in a similar setting, Nava\textsuperscript{13} reported positive effects of a PRP including lower-extremity exercise in COPD patients recovering from acute respiratory failure (ARF), which, in most cases, had required MV.

To our knowledge, there is no report of arm exercise in patients recovering from an episode of ARF needing MV but remaining in a high-dependency care unit. Therefore, we designed a multicenter, randomized, controlled study to evaluate whether the addition of supported arm exercise training (SAEx) to general physiotherapy (gPT) was feasible in a high-dependency unit like an RIICU, and if it resulted in additional benefits to gPT in patients recently weaned from MV.

Materials and Methods

The study was approved by the Ethical Committee of The Salvatore Maugeri Foundation, IRCCS and Gaiaeto Onlus Villa Pineta. Informed consent was given by each patient.

Patients

Patients with different diagnoses weaned from MV (either invasive or noninvasive) for $>48$ to $<96$ h were enrolled in the study. COPD was defined according to the American Thoracic Society criteria,\textsuperscript{14} or on the basis of high probability of the disease (ie, clinical history, physical examination, chest radiograph).

A two-parallel-group, prospective, randomized trial was carried out in 66 consecutive patients weaned from MV (via tracheostomy cannula, n = 55; via nasal or facial masks, n = 11) in the period from September 1999 to January 2002 in the RIICUs of Salvatore Maugeri Scientific Institutes of Gussago and Montesano and Gaiaeto Onlus Villa Pineta. These RIICUs are high-dependency units within departments of pulmonary rehabilitation, which are referral rehabilitation and chronic-care centers for large geographic areas in Northern Italy. Patients receiving long-term MV are admitted to these units to undergo a program of progressive discontinuation from MV or to be discharged to a home program of long-term ventilatory assistance if weaning attempt fails.\textsuperscript{15} Patients with ARF are also admitted and are treated by mask ventilation and, in case of failure, invasive MV.\textsuperscript{16}

All patients receiving MV via tracheostomy cannula were transferred to our RIICU from the ICUs of referring hospitals as difficult-to-wean patients. The time elapsed from intubation to tracheostomy ranged from 3 to 12 days. The time from intubation to RIICU admission ranged from 4 to 87 days. Weaning modalities in RIICUs were either spontaneous breathing trial periods or decreasing levels of inspiratory pressure support as described elsewhere.\textsuperscript{15} All patients receiving noninvasive ventilation underwent pressure-support ventilation delivered via nasal or face mask.

For the study purposes, patients were considered to be successfully weaned when they were able to tolerate at least 48 consecutive hours of spontaneous breathing without the occurrence of the following conditions: respiratory rate $>35$ breaths/min; $Pao_2 < 50$ mm Hg at a fraction of inspired oxygen ($Fio_2$) $\geq 0.4$; heart rate $>145$ beats/min; sustained changes in the heart rate (±20%) for at least 30 min; major arrhythmias requiring IV drug therapy; hemodynamic instability as assessed by systolic BP $>180$ mm Hg and $<70$ mm Hg at three consecutive measurements within 5 min and/or requiring therapy according to the doctor in charge; agitation and anxiety requiring IV sedation; and new appearance of diaphoresis.\textsuperscript{15,16}

In order to be randomized, patients had to be clinically stable as defined by values of arterial blood gases ($pH > 7.35$; $Pao_2 > 60$ mm Hg at $Fio_2 < 0.40$), absence of hyperthermia or infections, stability in hemodynamics, and a conscious and cooperative mental state.\textsuperscript{17} Patients were excluded if they had primary neurologic diseases, cerebrovascular diseases, myopathy, cardiovascular instability, severe arrhythmia, orthopedic problems, insufficient cooperative state, or any other condition involving inability to perform arm ergometry and/or to maintain the sitting upright position.

Measurements

General Characteristics: Demographic and anthropometric characteristics, ICU length of stay before RIICU admission, duration of the weaning process, and RIICU and hospital length of stay were recorded in all patients.

Lung Function: FEV\textsubscript{1} and FVC were measured at discharge by means of a mass flow sensor with volume integration (Vmax; SensorMedics; Yorba Linda, CA; and Master Scope; Jaeger; Hockberg, Germany) with the patients in the seated position according to standard procedure.\textsuperscript{18} The predicted values of Quanjer\textsuperscript{19} were used. Lung function data from 40 of 66 patients (60%) were available. Ten patients did not perform the functional maneuver; in 16 other patients, the obtained functional data were not acceptable and reproducible due to an incorrect maneuver and were discarded (7 patients in group 1, and 9 patients in group 2). Hence, data of the remaining 40 patients were analyzed: 35 patients who completed the study (group 1, n = 18; group 2, n = 17) and 5 patients who dropped out (group 1, n = 3; group 2, n = 2).

Arterial blood gases were sampled from the radial artery with the patients in semirecumbinent position while breathing supplemental oxygen to achieve an oxygen saturation measured by pulse oximetry $>90$%. $Pao_2$, $Paco_2$, and pH were measured by means of an automated analyzer (model 840; Ciba Corning; Medfield, MA).

Inspiratory muscle strength was assessed by measuring maximal inspiratory pressure (MIP) according to the most recent guidelines\textsuperscript{20} using a portable manometer (Ashcroft; Stratford, CT) with all patients breathing through a mouthpiece at the level of residual volume. At least three MIP maneuvers were performed, with 1-min interval between efforts, until two acceptable values not differing from each other by $>5$% were obtained; the highest value was considered for analysis. In tracheostomized patients, given the possibility to underestimate results due to leaks of air around the cannula and to resistance created by the cannula itself, spirometry and respiratory muscle function were assessed through a mouthpiece after closure of the external hole of a fenestrated and uncuffed cannula.

Arm Exercise Test: Symptom-limited incremental tests (ITs) by arm ergometry were performed on an isometric arm ergometer (Monark 851; Monark; Stockholm, Sweden) secured to a table at the shoulder level, using the standard 1-min incremental exercise protocol. After stabilization and a 1-min period of unloaded cycling at 40 to 45 cycles per minute, the load was increased by 2.5 W/min. The patients were strongly encouraged to exercise to the point of intolerable breathlessness, discomfort, or exhaustion.
until the maximal heart rate was achieved or abnormal ECG findings were noted (symptom-limited exercise test) or whenever the patient wanted to stop.

The endurance test (ET) was performed on the same arm ergometer at 50% of the peak work rate reached on the IT, cycling at 40 to 45 cycles per minute. The ET was performed the day after the IT. Patients were instructed to maintain this work rate until exhaustion. During both the IT and ET, ECG, oxygen saturation (Oxicap Monitor; Ohmeda; Louisville, CO), and respiratory rate were continuously monitored.

Patients were asked their perceived breathlessness (dyspnea) and arm muscular fatigue at rest and at peak exercise, and at isoload or isotime in the posttraining ITs and ETs, respectively, by pointing at a number or phrase on a 10-point modified Borg scale set in large type on a sheet in front of them. All measurements were performed and recorded under the supervision of a nurse not involved in the study.

**Study Protocol**

All eligible patients were assessed at baseline. The baseline ITs and ETs were performed by a physician not involved in the weaning process within 48 to 96 h after weaning from MV. After baseline assessments, the enrolled subjects were randomly assigned to one of the two groups by means of a computer-generated randomized list: patients in group 1 (study group) underwent a gPT program with the addition of SAEs on the arm ergometer used for the IT and ET; whereas patients in group 2 (control group) received gPT alone. The training program started within 96 h after weaning from MV. gPT consisted of six weekly 45-min daily sessions of assisted passive and progressively active lower- and upper-limbs mobilization, chest physiotherapy, assisted deambulation, functional and strengthening exercises, and respiratory rate and or without walking aids.

The type and duration of each gPT component were prescribed according to an arbitrary triage score consisting of the same three main domains (deambulation, trunk control, and cough efficiency), each ranging from 0 (complete autonomy) to 4 (highly compromised activity). In patients with a score ranging 0 to 5, gPT sessions consisted of 15 min of general mobilization, 15 min of ambulation assisted by a respiratory therapists, and 15 min of chest physiotherapy. In patients with a score ranging 6 to 9, gPT sessions consisted of 10 min of chest physiotherapy, 20 min of safe energy-efficient reciprocal pattern for gait, and 15 min of general mobilization. In patients with a score ≥ 10, the gPT session consisted of assisted passive and progressive active mobilization (30 min) and chest physiotherapy (15 min). The triage was administered every 3 days, and gPT was adjusted accordingly.

SAEs consisted of 15 daily supervised sessions of actual 20-min upper-arm cycling on the arm ergometer; the first session was conducted at 0 W, while the following 14 sessions were conducted increasing the load by 2.5 W per session according to the level of dyspnea and muscle fatigue scores and to the number of rest pauses (no more than 2 min of time out) allowed during training. The daily change by ± 1 step per point in Borg scale for dyspnea and muscle fatigue or ± 1 rest pause at the end of the session determined any cycling load increase or decrease in the next session.

**Definitions**

*Completers* were patients able to finish the 15 scheduled training sessions, whereas *dropouts* were patients who stopped prematurely the program due to clinical worsening as well as those patients in which for any reason the final assessment was lacking. Patients showing a postrehabilitation improvement equal to or exceeding the 75th percentile in peak workload during the IT and/or in endurance time during the ET (7.5 W and 10 min for the IT and ET, respectively) were defined as *improvers* independently of the randomized group.

**Statistical Analysis**

Statistical analysis was performed using SPSS software (release 12.0, SPSS; Chicago, IL). Descriptive data are shown as mean ± SD. The analyses were conducted on a intention-to-treat (all randomized patients) or per-protocol (all completers) basis. A two-sample t test was used to explore differences in baseline characteristics between intervention and control groups, between improvers and nonimprovers, and between completers and dropouts and to assess differences in changes of parameters following the rehabilitation program between intervention and control groups. Wilcoxon matched-pairs tests and Mann-Whitney U test were employed for nonparametric data. Frequency distributions were analyzed with χ² test.

A logistic regression model was applied to assess odd ratios (ORs) for the association of a significant improvement in IT and ET with all available baseline functional parameters. Comparisons between groups of improvers and nonimprovers for IT and ET for continuous variables were performed by means of one-way analysis of variance, whereas χ² test was applied to detect any differences in frequencies of corticosteroid, antibiotic, and bronchodilator use. We decided to include in the logistic regression analysis only those variables that in the one-way analysis of variance showed a level of significance ≤ 0.3. Therefore, only age, body mass index (BMI), PaCO₂, and MIP were included in the analysis. As no significant differences were observed between groups in frequencies of drug use, we decided not to include these variables in the logistic regression analysis. The final model was determined by stepwise logistic regression. The fit of the model was determined by the Hosmer-Lemeshow goodness-of-fit test; p< 0.05 was considered statistically significant.

**Results**

**Patients and Reasons for Dropout**

The trial profile is shown in Figure 1. During the study period, 228 patients were admitted to the three RICUs; 33% were COPD and 67% were non-COPD (25% amyotrophic lateral sclerosis and neurologic disease, 24% after cardiac surgery, 8% restrictive pulmonary disease, 7% neuromuscular disease, and 3% other diseases). Thirty-two of 228 patients (14%) died; 34 patients (15%) could not be weaned from MV and were discharged with home MV; 96 patients (42%) did not fulfill inclusion criteria because they presented with primary neurologic diseases, cerebrovascular diseases, myopathy, cardiovascular instability, severe arrhythmia, orthopedic problems, insufficient cooperative state, or other conditions resulting in the inability to perform arm ergometry and/or to maintain the sitting upright position.

The remaining 66 patients (29%) were considered eligible and entered the study. Fifty-five of the 66
eligible patients (83%) underwent tracheostomy; 11 patients (17%) were admitted to the RIICUs for mask ventilation due to an episode of ARF. Forty-six patients (70%) were COPD, 10 patients (15%) had restrictive chest wall diseases (fibrothorax, n = 6; kyphoscoliosis, n = 4), 6 patients (9%) had cardiosurgical sequelae, and 4 patients (6%) had diseases (septic sequel, n = 2; thoracic trauma, n = 1; abdominal surgical sequelae, n = 1). Thirty-one of 66 randomized patients (47%) were receiving long-term oxygen therapy before the episode of ARF.

Thirty-two patients were randomly assigned to group 1 (SAEx) and 34 patients were assigned to the control group (gPT). Baseline characteristics of the patients according to randomization are shown in Table 1. There were no significant differences in baseline characteristics between groups for any variables.

Twenty-five patients in each group (78% and 73% in groups 1 and 2, respectively) completed the study protocol (Fig 1). Causes for dropout were as follows: nosocomial pneumonia (one patient and three patients in groups 1 and 2, respectively), ARF without pulmonary infection (three patients and four patients, respectively), joint/muscular pain (three patients and one patient, respectively), and acute abdominal pain (one patient in group 2). Age, BMI, lung function, arterial blood gases, baseline MIP and peak work rate, and ICU length of stay before admission to the RIICU were not statistically different between the two groups when both the whole sample of enrolled patients or the sample of completers were taken into consideration. Likewise, no differences in the dropout rate was observed between the two groups, and between patients treated with noninvasive and invasive MV.

**Effects of SAEx on Maximal Workload and Endurance**

Both groups of patients had a significant improvement in maximum workload during the IT (from 9.7 ± 4.8 to 17 ± 8.8 W [p = 0.0001] and from 8.3 ± 4.4 to 11 ± 6.4 W [p = 0.001] for groups 1 and 2, respectively) [Fig 2 top left, A, and top right, B]. Similar results were found for ET: from 6.2 ± 4.5 to 14.1 ± 8.7 min (p = 0.0001) and from 5.7 ± 4 to 9.6 ± 6.4 min (p = 0.001) in groups 1 and 2, respectively (Fig 2, bottom left, C, and bottom right, D). A greater improvement was observed in group 1 compared to group 2 for both maximal effort: 7.3 W vs 2.6 W (p = 0.003) in groups 1 and 2, respectively; and ET: 8 min vs 4 min (p = 0.021) in groups 1 and 2, respectively (Table 2).
Both rehabilitation programs yielded a significant improvement in MIP (from 43 ± 19 to 52 ± 20 cm H₂O \( p < 0.001 \)) and from 37 ± 14 to 42 ± 15 cm H₂O \( p = 0.003 \) in groups 1 and 2, respectively) without any significant difference in the magnitude of improvement between groups \( p = 0.08 \) [Table 2].

**Effects of SAEx on Perceived Dyspnea and Muscular Fatigue**

Perceived dyspnea as assessed by Borg scale at the same workload of the IT (isoload) after the completion of the rehabilitation program decreased significantly:

\*\( p = 0.0001 \) vs before PRP; \*\*\( p = 0.001 \) vs before PRP.
significantly in both groups (from 4.6 ± 2.5 to 3.4 ± 2.7 [p = 0.005] and from 5 ± 3.2 to 3.5 ± 2.5 [p = 0.009] in groups 1 and 2, respectively) [Fig 3, top left, A] without any statistical difference in mean changes between groups (Table 2). Only SAEx, when compared to a control program, was able to reduce muscular fatigue during IT (from 6.3 ± 2.5 to 4.1 ± 2.8, p = 0.0007), as well as breathlessness (from 4.7 ± 2.8 to 2.6 ± 2.2, p = 0.007) and muscular fatigue (from 5.6 ± 2.6 to 3.4 ± 2.4, p = 0.002) during ET (Fig 3, top right, B; bottom left, C; bottom right, D). Improvement of muscular fatigue during the IT and dyspnea and muscular fatigue during the ET in group 1 almost reached statistical significance when compared to group 2 (Table 2).

### Improvers and Nonimprovers

Eleven of 25 patients (44%) in group 1 compared to 2 of 25 patients in group 2 (8%) [χ² = 0.004] demonstrated an improvement in IT after a rehabilitation program ≥75th percentile and were defined as IT improvers. Likewise, improvement of ET after a rehabilitation program was more frequent in group 1 than in group 2 (9 of 25 patients [36%] and 3 of 25 patients [12%] in groups 1 and 2, respectively; χ² = 0.047). According to these results, the number of patients to be trained with SAEx in adjunct to gPT necessary to obtain an IT improver was 2.8 (OR, 9; 95% confidence interval [CI], 2.63 to 2.97), whereas it was 4.17 (OR, 4; 95% CI, 3.98 to 4.35) to obtain an...
ET improver. Improvement in both IT and ET was observed in 7 of 25 patients (28%) in group 1 and 1 of 25 patients (4%) in group 2 ($\chi^2 = 0.021$).

Table 3 shows baseline characteristics of IT and ET improvers and nonimprovers according to the studied groups. Baseline MIP was significantly higher both in IT and ET improvers than in nonimprovers, whereas no other statistical difference was observed in baseline characteristics (Table 3).

When functional characteristics were included into a logistic regression model, in which the dichotomous variable was “improvers and nonimprovers,” only MIP, but neither days of stay in ICUs before admission in RIICU, nor age nor BMI, resulted to be independently significantly associated with an improvement in both IT (p = 0.013; OR, 1.116) and ET (p = 0.022; OR, 1.067) [Tables 4, 5]. In other words, at least in the population studied, a higher baseline MIP was associated with a higher likelihood of improvement in IT and ET results.

**Tracheostomized Patients**

When the group of tracheostomized patients (42 of 50 patients) was taken into consideration, previous results were somehow confirmed: mean change in IT was $8.1 \pm 7$ W in group 1 (gPT plus SAEx) and $2.4 \pm 3.2$ W in group 2 (gPT alone) [p = 0.002], whereas mean change in ET was $8.9 \pm 6.9$ min in group 1 (gPT plus SAEx) and $3.9 \pm 5$ min in group 2 (gPT alone) [p = 0.013].

**DISCUSSION**

This study shows the following: (1) the early addition of SAEx to gPT is feasible in a high-dependency unit like an RIICU in 30% of patients recently weaned from MV; in addition, 75% of eligible patients completed the study protocol; (2) the addition of SAEx to gPT enhances exercise capacity and reduces symptoms; and (3) baseline inspiratory muscle function is related to exercise capacity improvement. A point of major concern in patients admitted to ICUs and undergoing prolonged MV is muscular deconditioning following prolonged confinement to bed. Recently, a neurologic and muscular derangement due to sepsis, multiple organ failure, use of antibiotics, steroids or neuromuscular blockers drugs, named critical illness neuropathy and myopathy has been described in critical patients. In line with these evidences, early intervention aiming at functional recovery of different muscle groups would be beneficial in this particular clinical setting.

Little attention is usually dedicated to these problems in ICUs. This is underlined by a European survey focusing on the role of physiotherapists in European ICUs. In this study, the authors showed that in a sample of 102 European ICUs, only 75% had at least one physiotherapist working exclusively in the ICU, with an enormous difference in the number of physiotherapists therein employed. Fur-

**Table 3—Baseline Characteristics of Improvers and Nonimprovers***

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>IT Improvers (n = 13)</th>
<th>IT Nonimprovers (n = 37)</th>
<th>ET Improvers (n = 12)</th>
<th>ET Nonimprovers (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>69.0 ± 6.5</td>
<td>71 ± 5.6</td>
<td>70 ± 6.6</td>
<td>71 ± 5.8</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>70 ± 12</td>
<td>64 ± 17</td>
<td>69 ± 13</td>
<td>64.6 ± 17</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>25 ± 3.7</td>
<td>23 ± 6.4</td>
<td>25.3 ± 4</td>
<td>23.3 ± 6</td>
</tr>
<tr>
<td>PacO₂, mm Hg</td>
<td>49 ± 10</td>
<td>53 ± 11</td>
<td>53 ± 9</td>
<td>52 ± 12</td>
</tr>
<tr>
<td>PaO₂/Fio₂</td>
<td>252 ± 80</td>
<td>264 ± 72</td>
<td>237 ± 49</td>
<td>269 ± 79</td>
</tr>
<tr>
<td>Maximum watt at baseline</td>
<td>11.3 ± 5</td>
<td>9.2 ± 4.3</td>
<td>6.2 ± 3.6</td>
<td>5.7 ± 4.5</td>
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<tr>
<td>Minutes of effort at baseline</td>
<td>51.7 ± 21</td>
<td>36 ± 13</td>
<td>52 ± 19</td>
<td>36 ± 14</td>
</tr>
<tr>
<td>MIP at baseline, cm H₂O</td>
<td>19 ± 11.6</td>
<td>27 ± 22</td>
<td>16 ± 9.6</td>
<td>28 ± 21.4</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD. See Table 1 for expansion of abbreviation.
thermore, this survey showed that physiotherapists usually give enough attention to respiratory therapy, mobilization, and positioning, whereas they neglect early training sessions.

There is clear evidence that an inpatient PRP may be of benefit in patients with stable COPD or chronic lung diseases of different severity stages. Despite several position statements that have pointed out the importance of specific rehabilitation in an intensive environment for severely ill patients with different pathologies, the role of physiotherapy in ICU is still debated. In general, ICU sedation, particularly within 48 h from admission and mainly in patients receiving MV, is a major obstacle to the rehabilitation program. As already pointed out by Stiller, few publications have demonstrated the effectiveness of physiotherapy in the critically ill. In particular, there is low or even no evidence that physiotherapy in the critically ill is able to reduce complications, to improve pulmonary derangement, to shorten weaning process, as well as ICU and hospital length of stay, and to decrease morbidity and mortality. Moreover, there is no evidence that limb exercises prevent loss of joint range or increase muscle strength and function.

To date, there are few controlled studies assessing the role of PRPs including exercise training in patients recovering from a severe episode of acute ventilatory insufficiency requiring short-term or long-term MV. In a prospective randomized study, Nava showed the efficacy of a PRP including exercise training in patients with severe COPD recovering from a severe episode of ARF; however, not the whole of the patients included in this study had required MV, and most of them had already been discharged from the weaning center at the moment of their entry into the study. The main results of that study were postrehabilitation improvement of exercise capacity, reduction of dyspnea, and regained autonomy in activities of daily living.

Ntoumenopoulos et al. in a relatively small sample of 60 intubated critically ill patients receiving MV, reported a trend toward a reduction in nosocomial infections in the group of patients submitted to chest physiotherapy including gravity-assisted drainage, positioning, chest wall vibration, and airway suctioning via endotracheal tube, compared to patients receiving no respiratory physiotherapy. Zanotti et al. demonstrated that electrical stimulation improved peripheral muscles strength in a group of patients with characteristics similar to patients enrolled in our study (all recovering from ARF, receiving MV, and admitted to a weaning center). Finally, Greenleaf demonstrated the feasibility of an exercise training program in a miscellaneous group of patients with bed-rest deconditioning syndrome, and that the intermittent exercise training induced significant improvements in muscular endurance in comparison to patients not submitted to the training program.

Lower-limb training was the major component of all the cited rehabilitation programs. To our knowledge, there is no evidence of the effects of upper-limb training in patients recovering from an episode of ARF needing MV. Most patients with stable, moderate COPD complain of dyspnea during activities involving the upper extremities. In these patients, Celli et al. showed thoracoabdominal dysynchrony and increase in oxygen uptake and minute ventilation during unsupported arm activity, in comparison to middle-intensity leg exercise. An attractive explanation for this is that with increasing hyperinflation, inspiratory muscle predominance may shift from the diaphragm to the accessory respiratory muscles, including some muscles of the shoulder girdle that contribute to both upper-extremity positioning and pulmonary ventilation. In line with this concept, upper-extremity training would yield greater improvement (although not significantly) in MIP as observed in our study after training compared to the control group.

Few controlled studies have studied the effects of upper-limb training. Ries et al. showed that addition of arm training to leg exercise resulted in a significant improvement of a stable COPD patient’s functional status. Upper-limb exercise training can be accomplished using either supported arm exercise by ergometry or unsupported arm exercise by lifting free weights, dowels, and stretching elastic bands. Both methods can effectively improve arm endurance in stable chronic airflow obstruction patients. Our study confirmed the positive effects on endurance capacity (> 100%) of 15 consecutive arm-training sections also in severe patients recovering from an acute exacerbation.

Clark et al. investigated the effects of a special
program of isolated conditioning of peripheral skeletal muscle groups, including arm circling, in 48 COPD patients. These authors observed a greater improvement in endurance work and cardiorespiratory performance, together with a reduction in ventilation and breathlessness during exertion, in the trained patients compared to control subjects. Besides, this rehabilitation program resulted in an improvement in activity of daily living. Likewise, our study showed that a specific upper-extremity training program in adjunct to gPT is able not only to increase maximal workload and endurance of specific muscles, but also to reduce perceived dyspnea at rest and during task at the same workload (isowatt) and time (isotime) of the prerehabilitation testing, thus showing a clear training effect.

When feasibility of such a training program in critically ill patients is taken into consideration, our study showed that no more than one third of all patients admitted to an RIICU may be eligible for early arm-training programs, confirming all the limitations of a structured PRP in a setting with high level of care. However, the fact that dropout rates and number of patients able to complete the training program (completers) were not different between groups suggests the utility of upper-limb training even to more severe patients like those recently weaned from MV. Furthermore, our study confirms previous observations about the utility of gPT programs in severe patients in the RIICU and, uniquely, shows that the addition of supported upper-extremity training in these patients exerts greater improvements both in exercise tolerance and in perceived dyspnea and muscular fatigue, compared to patients undergoing gPT alone.

This study also shows that a good residual inspiratory muscle capacity after an episode of ARF predicts a significant improvement both in strength and endurance capacity following a specific training of the upper extremities. Interestingly and unexpectedly neither length of stay in the ICU nor age nor BMI influenced the effects of our rehabilitation programs.

A possible limitation of this study is the lack of a real control group in which no rehabilitation program at all was performed, in order to assess any possible interfering effects on improvement in exercise tolerance and inspiratory muscle strength resulting from nursing and medical care alone. Ethical considerations, i.e., any possible discrimination against patients left without any physiotherapy in such a delicate phase of recovery from ARF, suggested to avoid this approach. In this respect, our study was not designed to investigate potential effects of improvement of performance of upper-limb muscles on the clinical outcome of these patients. Further randomized studies are necessary for this purpose.

In summary, this study indicates that early upper-extremity exercise training can be safely and practically, even if not widely, performed on patients recently weaned from MV but still staying in a high-dependency unit and that it can enhance the effects of a gPT program on strength and endurance of upper-girdle muscles. A significant improvement in exercise tolerance of upper extremities following an early rehabilitation program is more likely to be expected in those patients with higher baseline inspiratory muscle strength. Therefore, upper-limb exercise training may be useful in the rehabilitation of critically ill patients recovering from ARF, and is worthy of further investigation.

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