Improvement of Peak Cough Flow After the Application of a Mechanical In-exsufflator in Patients With Neuromuscular Disease and Pneumonia: A Pilot Study

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Objective To investigate and demonstrate persistent increase of peak cough flow after mechanical in-exsufflator application, in patients with neuromuscular diseases and pneumonia.

Methods A mechanical in-exsufflator was applied with patients in an upright or semi-upright sitting position (pressure setting, +40 and −40 cmH₂O; in-exsufflation times, 2–3 and 1–2 seconds, respectively). Patients underwent five cycles, with 20–30 second intervals to prevent hyperventilation. Peak cough flow without and with assistive maneuvers, was evaluated before, and 15 and 45 minutes after mechanical in-exsufflator application.

Results Peak cough flow was 92.6 L/min at baseline, and 100.4 and 100.7 L/min at 15 and 45 minutes after mechanical in-exsufflator application, respectively. Assisted peak cough flow at baseline, 15 minutes, and 45 minutes after mechanical in-exsufflator application was 170.7, 179.3, and 184.1 L/min, respectively. While peak cough flow and assisted peak cough flow increased significantly at 15 minutes after mechanical in-exsufflator application compared with baseline (p=0.030 and p=0.016), no statistical difference was observed between 15 and 45 minutes.

Conclusion Increased peak cough flow after mechanical in-exsufflator application persists for at least 45 minutes.

Keywords Mechanical in-exsufflator, Neuromuscular diseases, Pneumonia, Peak cough flow
INTRODUCTION

Respiratory infection is the most common cause of hospitalization, in patients with neuromuscular diseases [1]. Especially, in patients with amyotrophic lateral sclerosis (ALS), respiratory complications due to excessive airway secretions and ineffective coughing, are principal causes of morbidity and mortality [2-4]. Among patients with Duchenne muscular dystrophy, 90% die of respiratory complications [5-7]. Thus, it is important to effectively remove airway secretions in patients with neuromuscular diseases, who have respiratory muscle weakness.

Effectiveness of the removal of airway secretions, depends on peak cough flow (PCF). According to previous studies, a PCF value of at least 160 L/min is needed for effective removal of airway secretions [1,8,9].

A mechanical in-exsufflator (MI-E) is used in patients with neuromuscular disease, with reduced PCF to remove airway secretions. By alternately applying positive and negative pressure to the airway, MI-E is used to remove secretions in the airway. This can be effectively used for removal of secretions in patients with respiratory infections with excessive sputum, as well as in patients with neuromuscular diseases showing decreased ability to voluntarily cough [10].

Previous studies have shown that PCF increases, during or immediately after MI-E application, in patients with neuromuscular disease, with reduced PCF to remove airway secretions [10-13]. However, it is unknown whether increased PCF persists for a certain period, after application of MI-E. Therefore, in addition to investigating effects of MI-E, this study examined changes in PCF before and after a certain period, from application of MI-E in patients with neuromuscular diseases showing decreased ability to voluntarily cough [10].

Study protocol

We applied the MI-E to patients according to protocol of our institute, based on cumulative experiences and other previous research. During the application, patients were in an upright or semi-upright sitting position. Settings of the MI-E were +40 cmH₂O and -40 cmH₂O pressure with insufflation and exsufflation times of 2–3 and 1–2 seconds, respectively [13]. Patients underwent a total of five cycles, with a pause of 20–30 seconds between each cycle to prevent hyperventilation [14].

PCF without assistance and assistive PCF (APCF) were evaluated sequentially as follow: PCF and APCF before MI-E application, PCF and APCF 15 minutes after MI-E, and PCF and APCF 45 minutes after MI-E. Non-assisted PCF was measured by asking the patient to inhale maximum amount of air unassisted, before coughing as hard as possible. APCF was measured by first asking the patient to inhale maximum amount of air unassisted, breathing in additional amount of air through a mask by using a manual resuscitator bag, and then an assistant applied a strong push to the patient’s abdomen while the patient was coughing [10]. Each process was repeated at least three times, and maximum value was selected from measurements (Fig. 1). Protocol was approved by the Institutional Review Board of Gangnam Severance Hospital (No. 3-2015-0149).

Statistical analysis was performed using IBM SPSS statistics version 20 (IBM, Armonk, NY, USA). Repeated-measures analysis of variance was used to compare values of PCF and APCF at each time, with Bonferroni correction for post hoc analysis.
RESULTS

A total of 27 patients (11 with Duchenne muscular dystrophy, 10 with progressive muscular dystrophy, 3 with ALS, 2 with spinal muscular atrophy, and 1 with limb-girdle muscular dystrophy) were included. Mean age was 30.0±13.3 years (range, 12–66 years), and 21 of them (77.8%) were men. All patients had a functional disability and could not walk without support. Twenty-four of them were using non-invasive ventilator support, and none of them was using invasive ventilator support (Table 1).

In baseline evaluation before application of MI-E, initial PCF value was 92.6±57.1 L/min and the APCF value was 170.7±66.0 L/min. At 15 minutes after application of MI-E, measured PCF was 100.4±57.2 L/min and the APCF was 179.3±12.9 L/min. At 45 minutes later, PCF was 100.7±60.9 L/min and the APCF was 184.1±14.5 L/min. The increase in PCF and that in APCF compared with their baseline values, were both statistically significant (p=0.001). Comparing baseline PCF and APCF with mea-

Table 1. Baseline characteristics of patients

| Characteristic                          | Value      |
|----------------------------------------|------------|
| Age (yr)                               | 30.0±13.3  |
| Sex                                    |            |
| Male                                   | 21         |
| Female                                 | 6          |
| Use of non-invasive ventilator          | 24 (82.8)  |
| Respiratory parameters                 |            |
| FVC (mL)                               | 652.4±296.6|
| FVC (% of predicted value)             | 16.6±8.9   |
| MIP (cmH₂O)                            | 16.6±9.4   |
| MIP (% of predicted value)             | 19.7±13.4  |
| MEP (cmH₂O)                            | 19.2±12.7  |
| MEP (% of predicted value)             | 16.3±13.5  |

Values are presented as mean±standard deviation or number (%).
FVC, forced vital capacity; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure.

Table 2. Measured PCF according to time

|                         | Before    | 15 min    | 45 min    | p-value a) | Post-hoc analysis (p-value) |
|-------------------------|-----------|-----------|-----------|------------|----------------------------|
|                         |           |           |           |            | Before vs. 15 min 15 min vs. 45 min |
| PCF (L/min)             | 92.6±11.0 | 100.4±11.0| 100.7±11.7| <0.001     | 0.030 0.016 >0.999       |
| APCF (L/min)            | 170.7±12.7| 179.3±12.9| 184.1±14.5| <0.001     | 0.016 0.158              |

Values are presented as mean±standard error.
PCF, peak cough flow; APCF, assisted peak cough flow.

a) Repeated-measure ANOVA.
sured value after 15 minutes, a statistically significant dif-
ference was found for both parameters (p=0.03, p=0.016).
However, comparing PCF and APCF values measured
after 15 minutes with those measured after 45 minutes,
peak flow was increased but the difference between time
points was not statistically significant (Table 2, Fig. 1).

DISCUSSION

This study demonstrated that PCF and APCF increase
for a certain period, after use of MI-E in patients with
neuromuscular disease and pneumonia. According to
previous studies, compared with unassisted coughing
and other standard cough augmentation techniques
(physiotherapy-assisted, non-invasive ventilator-assist-
ed, and exsufflation-assisted coughing), the MI-E sig-
nificantly increased PCF in patients with neuromuscular
disease [10-13]. However, although existing studies have
demonstrated increase in PCF during or immediately af-
ter use of MI-E, none of the studies showed whether the
effects persist for a certain period. This study is the first
to demonstrate increased PCF even after a certain period
after application.

Maintaining increased cough flow is more critical in
patients treated for current respiratory infection, because
all of them have coughing disability and trouble with
eliminating secretion. Nonetheless, whereas many previ-
ous studies usually excluded patients with pneumonia,
we chose patients treated for pneumonia.

Many patients with neuromuscular disease, have re-
spiratory muscle weakness that leads to declined lung
compliance. Consistent increase in PCF may be ex-
plained as increase in compliance of the lung and chest
wall. According to previous studies, lung compliance and
the capacity for breathing increased for 3 hours, upon
MI-E application in patients with kyphoscoliosis or ALS
[15,16]. We can assume that the forced vital capacity and
PCF, are increased temporarily by increased lung compli-
ance. Furthermore, increased cough flow may be due to
temporary conditioning, and strengthening effects on the
respiratory muscle of the stretching exercise [17]. Stret-
ching of respiratory muscles facilitates actin-myosin inter-
action, and strengthens respiratory muscles. Reduced
airway resistance after removal of respiratory secretions,
is also a probable mechanism, and has been proven in
many previous studies.

This study has limitations. We assumed that the 15 min-
utes time point reflects the short-term effect of MI-E and
45 minutes reflect the lasting effect. However, 45 minutes
is not sufficient time to reflect lasting effect of treatment.
Maximum insufflation capacity, maximal expiratory pres-
sure, and maximal inspiratory pressure were checked
only at baseline, and only PCF and APCF were checked
during follow-up. It is also a limitation that the mecha-
nism of increasing PCF, was not definitively explained.
A longer-termed and detailed evaluation is needed to
explain lasting effect of this treatment. Severity, type, and
disease course of pneumonia, as well as patient status at
the moment of evaluation during the hospital stay, were
not considered in detail, all of which could have an effect
on response to treatment with MI-E.

In addition, the training effect may also be considered.
It would be difficult to explain the consistent increase in
PCF after an intervention, as all subjects were repeatedly
evaluated in PCF and APCF consecutively during follow-
up periods also. Therefore, the training effect should be
considered, as repetitive instructions also increase sub-
jects’ compliance with using MI-E.

As this was not a blinded or randomized control study,
we could not conclude whether increased PCF affect
the course of pneumonia. The effect of increased PCF in
patients with neuromuscular disease and pneumonia
could have been more definitely evaluated, if another
group such as patients with pneumonia not using MI-E
or patients without pneumonia was compared. Further
case–control studies involving a large group of subjects
and more detailed evaluation, are needed to explain the
accurate mechanism for these effects.

In conclusion, increased ability to expectorate sputum
was confirmed after using MI-E, which persisted for at
least 45 minutes after therapy. MI-E is a useful device for
patients with neuromuscular disease and pneumonia,
not only as the best way to manage secretion, but also as
an intervention to maintaining coughing ability.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article
was reported.
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