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*Original Article / Özgün Makale*

# The use of Rapid Shallow Breathing Index shortens time to extubation in patients undergoing coronary artery bypass grafting

*Hızlı Yüzeyel Solunum İndeksinin kullanımı koroner arter baypas greftleme yapılan hastalarda ekstübasyon süresini kısaltır*

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***ABSTRACT***

***Background:*** This study aims to investigate the effects of the use of the Rapid Shallow Breathing Index on extubation success and time to extubation in patients undergoing elective isolated coronary artery bypass grafting.

***Methods:*** This prospective, randomized-controlled study included a total of 72 patients (55 males, 19 females; mean age 60.3±9.3 years; range 45 to 76 years) who underwent isolated coronary artery bypass grafting between February 2016 and November 2016. The patients were divided into two groups as the RSBI group (n=36) and the control group (n=36). The control group was extubated by conventional criteria that were routinely applied in our clinic, while the RSBI group was extubated, when the index scores became below 77 breaths per min/L, following ensuring hemodynamic stability and weaning procedure from mechanical ventilation.

***Results:*** The mean time to wean from mechanical ventilation was 5.8±1.0 hours in the RSBI group and 8.1±2.0 hours in the control group (p=0.03). Extubation protocol performed through the use of the index was found to provide 26% earlier extubation compared to the conventional extubation criteria. There was no significant difference in the postoperative follow-up parameters or clinical conditions.

***Conclusion:*** Our study results show that a practical tool such as the Rapid Shallow Breathing Index can be reliably used for making a decision in favor of extubation in patients undergoing coronary artery bypass grafting. A shortened time to extubation by the use of this index may provide substantial benefits in terms of prevention of infections, mechanical ventilation-induced lung injuries, and potential pulmonary complications.

***Keywords:*** Coronary artery bypass grafting; extubation; pulmonary complications; Rapid Shallow Breathing Index.

***ÖZ***

***Amaç:*** Bu çalışmada elektif izole koroner arter baypas greftleme yapılan hastalarda Hızlı Yüzeyel Solunum İndeks kullanımının ekstübasyon başarısı ve ekstübasyon süresi üzerindeki etkileri araştırıldı.

***Çalışma planı:*** Bu prospektif, randomize kontrollü çalışmaya Şubat 2016 - Kasım 2016 tarihleri arasında izole koroner arter baypas greftleme yapılan toplam 72 hasta (55 erkek, 19 kadın; ort. yaş 60.3±9.3 yıl; dağılım 45-76 yıl) alındı. Hastalar HYSİ grubu (n=36) ve kontrol grubu (n=36) olmak üzere iki gruba ayrıldı. Kontrol grubu kliniğimizde rutin olarak uygulanan konvansiyonel kriterlere göre ekstübe edilirken, HYSİ grubu, hemodinamik stabilizasyon sağlandıktan ve mekanik ventilasyondan ayrılma işleminden sonra indeks skorun 77 solunum L/dk. altına düştüğünde ekstübe edildi.

***Bulgular:*** Ortalama mekanik ventilasyondan ayrılma süresi HYSİ grubunda 5.8±1.0 saat ve kontrol grubunda 8.1±2.0 saat idi (p=0.03). Konvansiyonel ekstübasyon kriterlerine kıyasla, indeksin kullanıldığı ekstübasyon protokolü ile %26 daha erken ekstübasyon sağlandı. Ameliyat sonrası takip parametrelerinde veya klinik durumlarda anlamlı bir fark yoktu.

***Sonuç:*** Çalışma sonuçlarımız, Hızlı Yüzeyel Solunum İndeksi gibi pratik bir aracın, koroner arter baypas greftleme yapılan hastalarda ekstübasyon lehine karar vermede güvenle kullanılabileceğini göstermektedir. Bu indeksin kullanımı ile ekstübasyon süresinin kısalması; enfeksiyonların, mekanik ventilasyona bağlı akciğer hasarının ve muhtemel pulmoner komplikasyonların önlenmesi açısından ciddi yarar sağlayabilir.

***Anahtar sözcükler:*** Koroner arter baypas greftleme; ekstübasyon; pulmoner komplikasyonlar; Hızlı Yüzeyel Solunum İndeksi.

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Extubation and weaning of the patient from mechanical ventilation is one of the most critical steps of the postoperative period of coronary artery bypass grafting (CABG). Similar to delayed extubation, early extubation also has several drawbacks. Unnecessarily early extubation to avoid complications of prolonged ventilation is one of the major reasons for prolonged ventilation support following cardiac surgery.[1,2] Therefore, there is still a need for a scientific and objective definition of an early and successful extubation.

Although some centers perform early extubation by fast-track protocols in the intensive care unit after CABG, some others do the surgical procedures using higher cervical spinal anesthesia without any need for intubation.[3-6] Despite these advances, most clinics carry out weaning and extubation processes according to conventional extubation criteria to ensure hemodynamic stabilization and to monitor major complications such as bleeding. Although minimum criteria for hemodynamic stabilization and successful oxygenation were used in this conventional algorithm, it can be sometimes difficult to avoid unnecessary prolongation of mechanical ventilation. First described by Yang and Tobin[7] in 1991 as the breathing rate per tidal volume, the Rapid Shallow Breathing Index (RSBI) is a tool with a high predictive value of indicating extubation failure. This index is mainly based on the significant association of compliance and inspiratory effort to the gas exchange and breathing rate. It can be easily recalled and calculated, although there is a limited number of reports showing that the RSBI is able to prevent unnecessary prolongation of duration of intubation.[8]

In the present study, we aimed to investigate the effects of the use of the RSBI on extubation success and time to extubation in patients undergoing elective isolated CABG.

## PATIENTS AND METHODS

This prospective, randomized-controlled, clinical study included a total of 72 patients (55 males, 19 females; mean age 60.3±9.3 years; range 45 to 76 years) who underwent isolated CABG between February 2016 and November 2016. A written informed consent was obtained from each patient. The study was approved by the Ethics Committee of Hitit University, School of Medicine (No: 2016-35). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The patients were divided into two groups as the RSBI group (n=36) and the control group (n=36) using basic randomization technique through online randomization software (www.randomizer.org). The control group was extubated by conventional criteria which we performed routinely in our clinic, while the RSBI group was extubated, when the RSBI scores were below 77 breaths per min/L, following ensuring hemodynamic stability and weaning from mechanical ventilation. Anesthetic regimens, cardiopulmonary bypass (CPB), and surgical procedures were performed in a standard fashion in all cases. Anesthesia induction consisted of fentanyl, midazolam, and thiopental sodium and tracheal intubation was facilitated by pancuronium bromide. All patients were intubated with 8 mm orotracheal tube. Mild hypothermia (32˚C) was used, and the patients were ventilated with low-tidal volume (2-3 mL/kg) during CPB.

### Eligibility criteria

Only the volunteer patients who underwent elective isolated CABG were included in this study. Those undergoing additional cardiac surgical interventions or who were operated in the emergency setting were excluded. In addition, those with hemodynamic instability, using intra-aortic balloon pumps, reoperation due to complications, use of sedatives for any reasons, auto-extubation, those who were defined as difficult intubation due to the use of auxiliary intubation methods upon failure of standard intubation by the anesthesiologist, and those with a current or past medical treatment for any psychiatric disorder were also excluded.

### Data collection

Preoperative demographic and clinical data, time to extubation, post-extubation partial pressure of oxygen ($PaO_2$), partial pressure of carbon dioxide ($PaCO_2$), and pH values (the mean of consecutive three measurements was recorded) at two hours, and the need for non-invasive mechanical ventilation and pulmonary complication after extubation were recorded. The number of coronary grafts, operation times, and the use of CBP were also noted.

Telecardiogram was performed routinely in the morning of postoperative Day 1 and atelectasis was evaluated. Pneumonia, respiratory failure, and requirement of re-intubation were recorded.

### Extubation criteria

After surgery, the patients were weaned from the mechanical ventilator, when the following criteria were met:

*Weaning criteria:*[9]

- Restoring of awareness and neuromuscular blockade by mild stimuli (restoring of muscular strength)
- Normothermia (>36˚C)
- Amount of drainage <50 mL/hour
- Sufficient cardiac performance
  - Cardiac index >2 l/min/$m^2$
  - Systolic blood pressure >100-120 mmHg
  - Heart rate <120 bpm and absence of arrhythmia
  - Absence of arrhythmia
- Arterial blood gases (ABG)
  - $PaO_2$/fraction of inspired oxygen ($FiO_2$) >150
  - $PaCO_2$ <50 mmHg
  - pH 7.35-7.45

The patients with adequate muscular strength (i.e., those who were able to lift his/her head >30° from the bed and easily resist against the pressure applied on the hands and feet) and spontaneous awakening were switched to the continuous positive airway pressure (CPAP) mode of the mechanical ventilator. After remaining at this mode for 15 min, extubation was decided according to the conventional criteria or the RSBI readings. As described in the literature, the RSBI was calculated by dividing the patient's breath count to the tidal volume.[7] The RSBI score used in the present study was automatically calculated by the mechanical ventilator device (Engström Carestation, 2012, Datex-Ohmeda© Inc., Wisconsin, USA). The threshold used for the extubation in these cases was 77 breaths per min/L, as reported by Takaki et al.[10] The rationale to choose this threshold rather than 105 breaths per min/L was to increase the specificity from 64 to 89% in this vulnerable patient population.[9,10]

**Statistical analysis**

Statistical analysis was performed using the SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA). Nominal data were expressed in number and percentage and analyzed using the Pearson's chi-square or Fisher's exact test. Continuous data were expressed in mean + standard deviation (SD) and range. Homogeneity tests were used to assure similar distribution between the groups, whereas means were compared using an unpaired t-test. The pre- and postoperative data comparison within a group was performed using a paired t-test, where applicable. A $p$ value of <0.05 was considered statistically significant.

## RESULTS

Both groups were similar in terms of accompanying diseases, the number of coronary grafts, and use CPB (Table 1). However, the patients in the RSBI group were likely to be younger, compared to the control group (62.6±9.1 vs 58.1±9.4, p=0.04).

According to the time to extubation, the patients in the RSBI group were observed to wean from

**Table 1. Preoperative demographic and clinical characteristics of study groups**

| Study patients | Control group (n=36) | | | RSBI group (n=36) | | | |
|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | n | % | Mean±SD | *p* |
| Age (year) | | | 62.6±9.1 | | | 58.1±9.4 | 0.04 |
| Gender | | | | | | | |
| Male | 26 | 72 | | 29 | 80 | | 0.58 |
| Chronic obstructive pulmonary disease | 11 | 30 | | 15 | 41 | | 0.46 |
| Asthma | 4 | 11 | | 3 | 8 | | 1 |
| Diabetes mellitus | 12 | 33 | | 9 | 25 | | 0.60 |
| Arterial hypertension | 20 | 55 | | 19 | 52 | | 1 |
| Hyperlypidemia | 19 | 52 | | 16 | 44 | | 0.63 |
| Body mass index | | | 29.7±6.5 | | | 31±7.0 | 0.12 |
| Ejection fraction (%) | | | 55.0±8.1 | | | 51.6±8.9 | 0.04 |
| Bypass graft number | | | 3.3±1.4 | | | 2.8±1.3 | 0.06 |
| On-pump surgery | 14 | 38 | | 13 | 36 | | 1 |
| Operation time (hours) | | | 5.3±1.2 | | | 4.9±1.0 | 0.78 |
| Cardiopulmonary bypass time (min) | | | 100.8±27.4 | | | 98±19.9 | 0.56 |
| Cross-clamp time (min) | | | 82.3±24.2 | | | 79±21.6 | 0.49 |

SD: Standard deviation.

**Table 2. Post-extubation parameters among groups**

| Study patients | Control group (n=36) | | | RSBI group (n=36) | | | |
|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | n | % | Mean±SD | *p* |
| Extubation time (hours) | | | 8.1±2.0 | | | 5.80±1.0 | 0.03 |
| Post-extubation $PO_2$ (mmHg) | | | 85.9±13.4 | | | 82.9±11.7 | 0.32 |
| Post-extubation $PCO_2$ (mmHg) | | | 34.2±2.4 | | | 36.6±3.4 | 0.02 |
| Post-extubation pH | | | 7.4±0.1 | | | 7.4±0.1 | 0.6 |
| Non-invasive mechanical ventilation support | 3 | 8.3 | | 9 | 25 | | 0.11 |

SD: Standard deviation.

mechanical ventilation after a mean of 5.8±1.0 hours, compared to 8.1±2.0 hours in those who were extubated through conventional methods, indicating a statistically significant difference (p=0.03) (Table 2).

Although one-hour post-extubation $PaO_2$ and pH values were not significantly different between the groups, one-hour $PaCO_2$ was significantly higher in the RSBI group (p=0.02). However, this was never found to be above 45 mmHg in none of the patients (range, 30 to 45 mmHg, median: 35 mmHg).

In the control and RSBI groups, the rate of the patients (8% [n=3] and 25% [n=9], respectively; p=0.11) to whom noninvasive mechanical ventilation (on bilevel positive airway pressure [BiPAP] mode and positive end-expiratory pressure [PEEP]: 5 mmHg, pressure support: 7 mmHg) was applied during the post-weaning period in the intensive care unit due to hypercapnia ($PCO_2$ >40 mmHg), hypoxemia ($PO_2$ <60 mmHg), or presence of atelectasis on telecardiography was similar.

The patients who were followed in the intensive care unit following extubation were also assessed in terms of occurrence of any re-intubation, respiratory failure and pneumonia, and none developed these complications. In addition, none of the patients required prolonged intensive care follow-up or experienced all-cause mortality.

## DISCUSSION

The present study showed that extubation protocol performed via the RSBI provided a 26% earlier extubation, compared to the conventional extubation criteria.

It is well-established that early extubation following cardiac surgery has several benefits including favorable clinical outcomes and low medical costs.[11-14] Although pulmonary complications are frequently seen after CABG, severe complications are rare. The prevention of infections and protective measures against mechanical ventilation-induced lung injuries play a critical role to avoid these complications.[15] Therefore, shortened time to extubation as achieved using the RSBI may offer substantial benefits in terms of preventing these complications and reducing health-related costs.

In the early 1990s, several reports of successful extubation of selected patient groups at the postoperative second to third hours during recovery area, which led to the development of fast-track protocols that rapidly disseminated throughout the world.[16] One of the critical steps of the fast-track protocol is the extubation process which is performed by the fourth hour postoperatively. In these protocols, operative strategies such as beating-heart surgery and mild hypothermia are more often applied, and anesthetic practices such as long-acting neuromuscular blockade or high-dose opioids are avoided to establish early extubation.[16] In the present study, we did not apply fast-track protocol; however, we reached a mean of 5.8 hours until extubation with the use of the RSBI.

Prolonged extubation may lead to morbidity and mortality-related complications such as diaphragmatic atrophy, venous thromboembolism, delirium, and pneumonia by elevating the stress in cardiovascular and pulmonary systems.[17-21] Therefore, numerous criteria or indices have been designated to address weaning from the ventilator, yet none of them has been proved to be superior to another.[22] Using vital capacity, maximum inspiratory capacity, and ventilation per min parameters in 1991, Yang and Tobin[7] introduced and showed the reliability of the RSBI to establish a safe extubation and avoid re-intubation. They predicted high weaning failure for the values above 105 breaths/min/L. They performed the measurements by connecting a hand spirometer to an endotracheal tube at the room temperature. The aforementioned authors showed that a successful weaning was able to be made in patients having <105 breaths/min/L with a 97% sensitivity, 64% specificity, 78% positive

predictive value, and 95% negative predictive value. Subsequently, several studies reported successful outcomes and utilization of this index in adult and pediatric patients.[23-25] Some other studies compared the RSBI, CPAP, and T-tube extubation and reported that the weaning achieved by the RSBI was more reliable than the others.[26,27] Lessa et al.[28] reported the ability of ventilators to measure the RSBI index and concluded that accurate measurements could be also achieved by the parameters on the ventilators.[28]

Several studies reported that, in patients undergoing cardiac surgery, outcomes such as failure of extubation and prolonged intubation to avoid a failed extubation were associated with certain preoperative conditions, such as congestive heart failure, hypoalbuminemia, low arterial oxygen pressure, and anemia.[29]

Some authors showed that several factors such as ejection fraction (EF) and body mass index influenced successful extubation and re-intubation.[30] These factors were found to play a key role for the respiratory tolerance after cardiac surgery. It was reported that the patients with decreased EF were more likely to develop respiratory problems than that with normal EF.[30,31] Nevertheless, consideration of merely EF is not sufficient to assess time to extubation, since these patients usually manifest increased catecholamine, sedative use, and volume imbalance. In addition, the EF values were slightly higher in the conventional extubation group in our study.

Obesity is one the preoperative risk factors for complications of cardiac surgery.[32] It was reported that prolonged postoperative intubation was more common in obese patients than non-obese individuals.[33] In addition, early intubation was shown to be more unsuccessful in obese patients.[34] Therefore, various modifications of the RSBI were offered and studied such as adjusted the RSBI scores for the actual body weight, predicted body weight, ideal body weight, body mass index, and body surface area. These modifications may be chosen for obese patients and in heterogeneous cohorts.[10]

In Turkey, postoperative intensive care follow-up of patients undergoing cardiac surgery is managed by cardiovascular surgeons. Clinical decisions such as hemodynamic monitoring, extubation period, re-intubation indications, need for reoperation and indications, and discharge from the intensive care unit are all made by the surgeons. In addition to these risk factors, hemodynamic instability, intensive use of medications that either decrease or increase contractility, and the clinical decision of the surgeon itself, even if all the criteria are met, may prolong the time to extubation. Cardiovascular clinics in Turkey differ in terms of anesthesia and intensive care monitoring and medication protocols. While early extubation is often reserved for those who are elderly or likely to develop pulmonary complications, we follow the patients with high-risk or difficult intubation, or who are using intensive anticoagulants and antiplatelets during the perioperative period as intubated, until hemodynamic parameters and the amount of the drainage become stable. Therefore, the intubation time of certain patients can be prolonged at the expense of the surgeon subjectively, which in turn, renders some patients with an increased rate of pulmonary complications. These warrant the need for reliable and objective parameters such as the RSBI for the postoperative follow-up of cardiac patients.

Although our study was not designated to show benefits or advantages of early extubation, its accuracy is well-proven and recognized with many studies as mentioned above. Long-term or potentially relevant effects of the observed intragroup difference for the time to extubation were not examined. Further long-term research is needed to address this question. While the limited number of our cases compared to a very wide spectrum of cardiac surgical patients is an important limitation, prospective and randomized study design with a lack of preoperative difference between the groups appears to reduce the impact of this disadvantage. The subjectivity imposed by the decision of the surgeon who followed the patients extubated by conventional methods is a very challenging situation faced by all these types of studies. Since it was impossible to build a double-blind method, we reviewed extubation periods of our previous patients in order to notice a potential bias, and observed that these were consistent with that our control group. This observation supports the notion that the control group was not affected by a potential bias in this non-double-blind study. Finally, we only included elective CABG patients. Therefore, our findings about the effects of early extubation merely reflect those on a specific patient population. On the other hand, since there are numerous additional parameters influencing extubation in emergent cases and concomitant cardiac interventions, these were excluded from the study. It would be also very difficult to detect or show the isolated effect of the RSBI in such a heterogeneous population.

In conclusion, our study results show that a practical tool such as the Rapid Shallow Breathing Index can be reliably used for making a decision in favor of extubation in patients undergoing coronary artery bypass grafting.

A shortened time to extubation by the use of this index may provide substantial benefits in terms of prevention of infections, mechanical ventilation-induced lung injuries, and potential pulmonary complications.

**Declaration of conflicting interests**

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