MAGNITUDE AND PATTERN OF BREATHING EFFORT AFTER CARDIAC SURGERY

Preliminary Results of the EFFORT study

AUTHORS

A. GRASSI[1], I. TELIAS[2,3], M.C. SKLAR[2,3], A. CATSELLVI FONT[4,5], D. JUNHASAVASDIKUL[2], D.L. GRIECO[2], M. DRES[2], T. PIRAINO[2], T. PHAM[2], A. KIM[2], L.F. DAMIANI[2], R. MELLADO-ARTIGAS[2], L. MELO[2], K. HAN[6], A. SLABIAK[2], S. BRODUTCH[7], D.C. MAZER[6], L. BROCHARD[2,3], E.C. GOLIGHER[3,5]

1 Department of Anesthesiology and Pain Medicine, Toronto General Hospital, University of Toronto, Toronto, ON, Canada

2 Keenan Research Centre for Biomedical Science, Li Ka Shing Knowledge Institute, Unity Health Toronto, Toronto, ON, Canada
3 Interdepartmental Division of Critical Care, University of Toronto, Toronto, Canada

4 University Health Network, Department of Medicine, Division of Respirology, Toronto, Ontario, Canada.

5 Toronto General Hospital Research Institute, Toronto, Ontario, Canada

6 Department of Anesthesia, St. Michael's Hospital, University of Toronto
7 Department of Cardiac Surgery, St Michael's Hospital, University of Toronto, Toronto, Ontario, Canada

CONTACT INFORMATION

alice.grassi@uhn.ca

INTRODUCTION

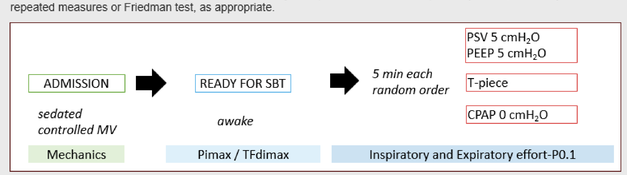
Cardiac surgery patients have a high rate of successful liberation from mechanical ventilation despite diaphragm dysfunction and lung abnormalities (1). Quantifying the magnitude of breathing effort and describing their breathing pattern in detail can be useful to define an acceptable range of effort and understand breathing patterns that these and other critically ill patients can use to compensate for diaphragm dysfunction (2).

OBJECTIVES

1. To describe inspiratory effort around extubation in stable patients after cardiac surgery.
2. To assess the incidence of diaphragmatic dysfunction.
3. To assess the use of accessory and expiratory muscles.

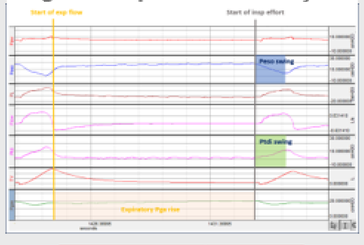
METHOD

Patients after elective, uncomplicated, cardiac surgery were included.
The study steps are illustrated in the Figure below.
20 breaths for each condition were selected and analyzed for:
- tidal volume (TV) and respiratory rate (RR)
- inspiratory effort and drive (Esophageal Pressure Swing (Peso Swing), Esophageal Pressure Time Product per minute (PTPeso,min), p0.1), Tension Time Index of the inspiratory muscles (TTI), calculated as (Peso Swing/Maximum Peso) * (Inspiratory Time / Total Time).
- diaphragm activity (thickening fraction (TF,di) measured with ultrasound, and Tension Time Index (TTIdi), calculated as (Transdiaphragmatic pressure (Ptdi) per breath / maximum Ptdi) * (Inspiratory Time / Total Time)) (3)
- expiratory muscles use (change in expiratory gastric pressure (Expiratory Pga Decay)), and their relative contribution to inspiration (calculated as (Peso Swing – corrected Peso Swing)/Peso Swing, where corrected Pes Swing = (Peso Swing – Expiratory Pga Decay) (4)
- Results are expressed as mean [Standard Deviation]. The parameters were compared by T test, One Way ANOVA for repeated measures or Friedman test, as appropriate.



RESULTS

Fig. 1 Example of Trace Analysis



Population n=18	
Males n(%)	17 (94.4%)
Age (years)	62.7 ± 10.0
BMI	29.0 ± 5.9
Cpl_{RS} (ml/cmH_2O)	37.1 ± 7.4
Cpl_{CW} (ml/cmH_2O)	134.0 ± 47.1
Cpl_L (ml/cmH_2O)	56.4 ± 18.5
Indices of Maximal Effort	
Pi,max (cmH_2O)	27.9 ± 12.0
Pdi,max (cmH_2O)	17.0 ± 12.2
Peso,max (cm H_2O)	21.2 ± 10.3
TF,di max	0.42 ± 0.26
Outcome	
ICU Length of stay (days)	1.2 ± 0.5

Fig. 2 Inspiratory Drive and Effort

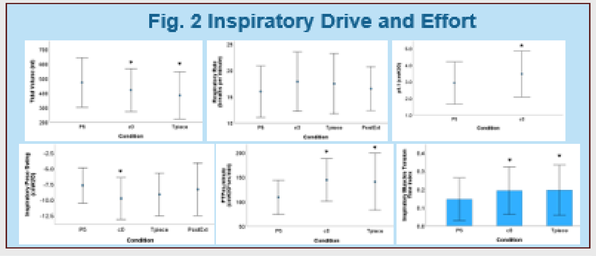


Fig. 3 Diaphragm Function

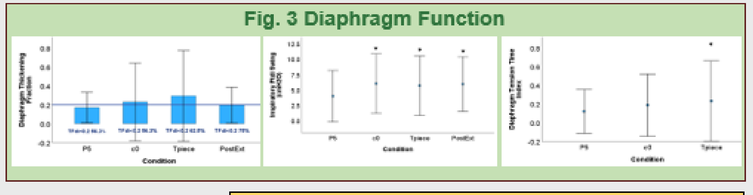
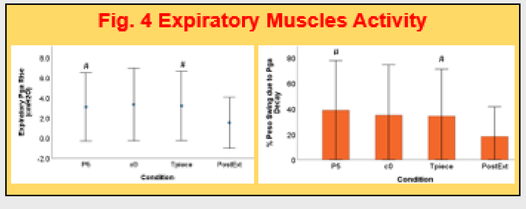


Fig. 4 Expiratory Muscles Activity



Cpl_{RS}, Cpl_{CW} Cpl_L Compliance of Respiratory System, of the Chest Wall and of the Lung (respectively)
Pi,max Maximum Inspiratory Pressure. Ptdi,max Maximum Transdiaphragmtic Pressure. TF,di max Maximum Diaphragmatic Thickening Fraction.
PS Pressure Support 5 on PEEP 5 cmH_2O. C0 continuous Positive Airway Pressure 0cmH_2O. PostExt Post Extubation. Peso Esophageal Pressure. Pga Gastric Pressure. PTP Pressure Time Product. Ptdi Transdiaphragmatic Pressure.
Inspiratory Muscles Tension Time Index = (Peso Swing/PesoMax)^/)/(Inspiratory Time/Total Time)
Diaphragm Tension Time Index = (Ptdi/Pdimax)/(Inspiratory Time/Total Time).
% Pga swing due to Pga Rise = (Peso Swing-corrected Peso Swing)/Peso Swing where corrected Peso Swing = Peso Swing – Expiratory Pga decay (2)
* p<0.05 vs PS, # < 0.05 vs PostExt

CONCLUSION

Despite a high incidence of diaphragm dysfunction, stable patients after elective cardiac surgery show an appropriate increase of inspiratory effort with increasing load. The use of accessory and expiratory muscles is common and seems to contribute to the generation of the inspiratory effort. This study generates the hypothesis that in the specific population of patients who underwent cardiac surgery, the use of expiratory muscle is a beneficial contributor to the process of liberation from mechanical ventilation.

ACKNOWLEDGEMENTS

The authors thank Dr Andrea Castellvi for her contribution to trace analysis

REFERENCES

1. Moury PH, Cuisinier A, Durand M, et al.: Diaphragm thickening in cardiac surgery: a perioperative prospective ultrasound study. *Ann Intensive Care* 2019; 9
2. Goligher EC, Dres M, Patel BK, et al.: Lung- And diaphragm-protective ventilation. *Am J Respir Crit Care Med* 2020; 202:950–961
3. Diehl JL, Lofaso F, Deleuze P, Similowski T, Lemaire F, Brochard L. Clinically relevant diaphragmatic dysfunction after cardiac operations. *J Thorac Cardiovasc Surg* 1994;107(2):487-98
4. Parthasarathy S, Jubran A, Laghi F, Tobin MJ. Sternomastoid, rib cage, and expiratory muscle activity during weaning failure. *J Appl Physiol* (1985). 2007;103(1):140-7

INTRODUCTION

Cardiac surgery patients have a high rate of successful liberation from mechanical ventilation despite diaphragm dysfunction and lung abnormalities (1). Quantifying the magnitude of breathing effort and describing their breathing pattern in detail can be useful to define an acceptable range of effort and understand breathing patterns that these and other critically ill patients can use to compensate for diaphragm dysfunction (2).

OBJECTIVES

1. To describe inspiratory effort around extubation in stable patients after cardiac surgery.
2. To assess the incidence of diaphragmatic dysfunction.
3. To assess the use of accessory and expiratory muscles.

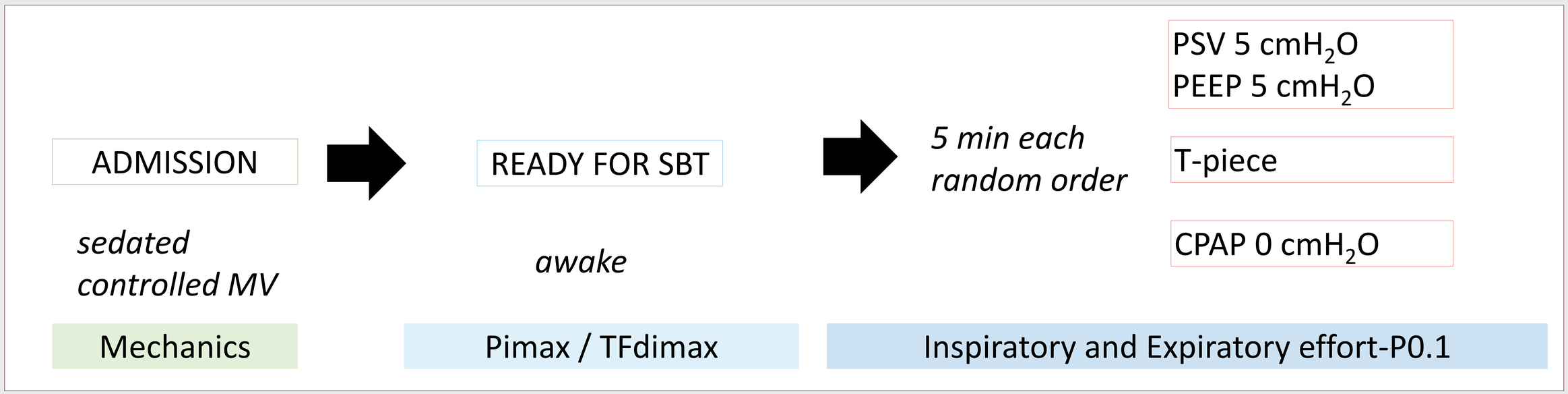
METHOD

Patients after elective, uncomplicated, cardiac surgery were included.

The study steps are illustrated in the Figure below.

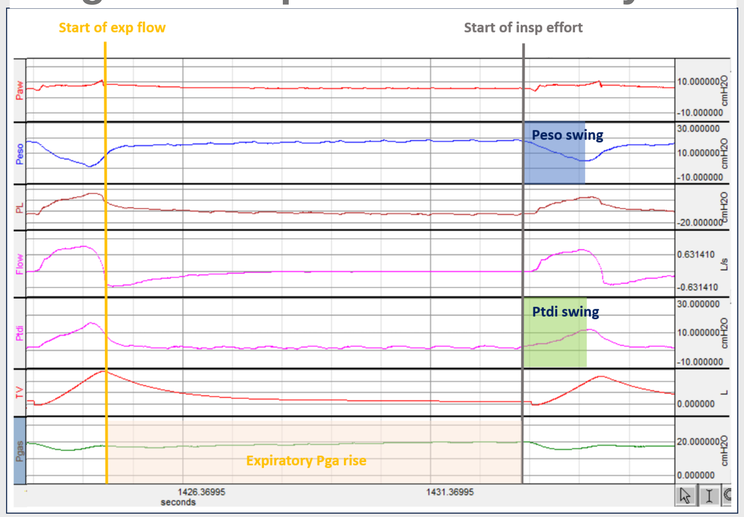
20 breaths for each condition were selected and analyzed for:

- tidal volume (TV) and respiratory rate (RR)
- inspiratory effort and drive (Esophageal Pressure Swing (Peso Swing), Esophageal Pressure Time Product per minute (PTPeso,min), p0.1), Tension Time Index of the inspiratory muscles (TTI), calculated as (Peso Swing/Maximum Peso) * (Inspiratory Time / Total Time).
- diaphragm activity (thickening fraction (TF,di) measured with ultrasound, and Tension Time Index (TTIdi), calculated as (Transdiaphragmatic pressure (Ptdi) per breath / maximum Ptdi) * (Inspiratory Time / Total Time)) (3)
- expiratory muscles use (change in expiratory gastric pressure (Expiratory Pga Decay)), and their relative contribution to inspiration (calculated as (Peso Swing – corrected Peso Swing)/Peso Swing, where corrected Pes Swing = (Peso Swing – Expiratory Pga Decay) (4)
- Results are expressed as mean [Standard Deviation]. The parameters were compared by T test, One Way ANOVA for repeated measures or Friedman test, as appropriate.



RESULTS

Fig. 1 Example of Trace Analysis



Population n=18	
Males n(%)	17 (94.4%)
Age (years)	62.7 ± 10.0
BMI	29.0 ± 5.9
Cpl_{RS} (ml/cmH_2O)	37.1 ± 7.4
Cpl_{CW} (ml/cmH_2O)	134.0 ± 47.1
Cpl_{L} (ml/cmH_2O)	56.4 ± 18.5
Indices of Maximal Effort	
Pi,max (cmH_2O)	27.9 ± 12.0
Pdi,max (cmH_2O)	17.0 ± 12.2
Peso,max (cmH_2O)	21.2 ± 10.3
TF,di max	0.42 ± 0.26
Outcome	
ICU Length of stay (days)	1.2 ± 0.5

Fig. 2 Inspiratory Drive and Effort

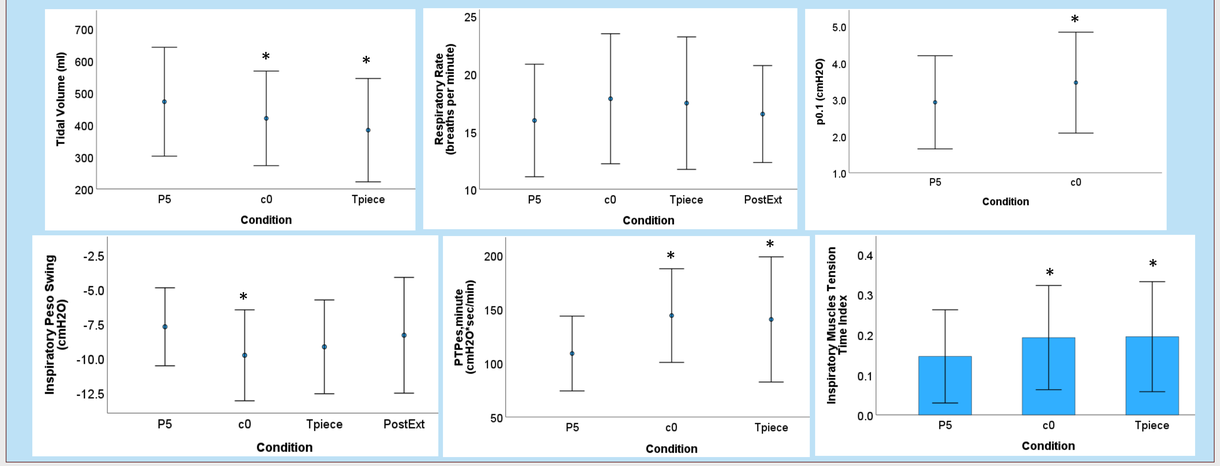


Fig. 3 Diaphragm Function

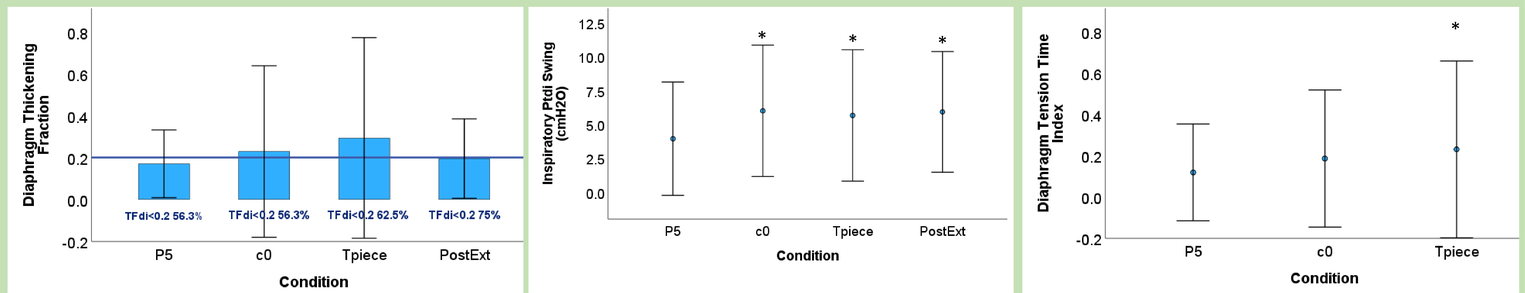
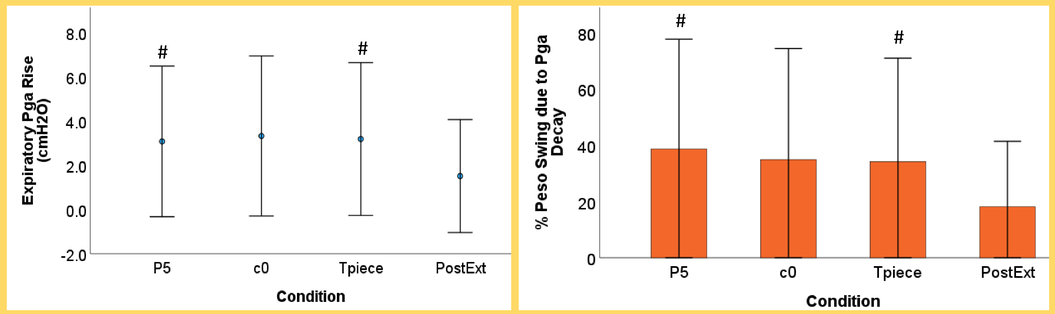


Fig. 4 Expiratory Muscles Activity



Cpl_{RS}, Cpl_{CW}, Cpl_{L} Compliance of Respiratory System, of the Chest Wall and of the Lung (respectively)
Pi,max Maximum Inspiratory Pressure. Ptdi,max Maximum Transdiaphragmtic Pressure. TF,di max Maximum Diaphragmatic Thickening Fraction.
P5 Pressure Support 5 on PEEP 5 cmH_2O. C0 continuous Positive Airway Pressure 0cmH_2O. PostExt Post Extubation. Peso Esophageal Pressure. Pga Gastric Pressure. PTP Pressure Time Product. Ptdi Transdiaphragmatic Pressure.
Inspiratory Muscles Tension Time Index = (Peso Swing/PesoMax)/)/(Inspiratory Time/Total Time)
Diaphragm Tension Time Index = (Ptdi/Pdimax)/(Inspiratory Time/Total Time).
% Pga swing due to Pga Rise = (Peso Swing-corrected Peso Swing)/Peso Swing where corrected Peso Swing = Peso Swing – Expiratory Pga decay (2)
* p<0.05 vs P5, # < 0.05 vs PostExt

CONCLUSION

Despite a high incidence of diaphragm dysfunction, stable patients after elective cardiac surgery show an appropriate increase of inspiratory effort with increasing load. The use of accessory and expiratory muscles is common and seems to contribute to the generation of the inspiratory effort. This study generates the hypothesis that in the specific population of patients who underwent cardiac surgery, the use of expiratory muscle is a beneficial contributor to the process of liberation from mechanical ventilation.

ACKNOWLEDGEMENTS

The authors thank Dr Andrea Castellvi for her contribution to trace analysis

REFERENCES

1. Moury PH, Cuisinier A, Durand M, et al.: Diaphragm thickening in cardiac surgery: a perioperative prospective ultrasound study. *Ann Intensive Care* 2019; 9
2. Goligher EC, Dres M, Patel BK, et al.: Lung- And diaphragm-protective ventilation. *Am J Respir Crit Care Med* 2020; 202:950–961
3. Diehl JL, Lofaso F, Deleuze P, Similowski T, Lemaire F, Brochard L. Clinically relevant diaphragmatic dysfunction after cardiac operations. *J Thorac Cardiovasc Surg* 1994;107(2):487-98
4. Parthasarathy S, Jubran A, Laghi F, Tobin MJ. Sternomastoid, rib cage, and expiratory muscle activity during weaning failure. *J Appl Physiol* (1985). 2007;103(1):140-7

CONTACT INFORMATION

alice.grassi@uhn.ca