Protective ventilation improves gas exchange and affects metabolic response after major abdominal surgery

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Background & Goal

In major abdominal surgery, protective peri-operative ventilation with low tidal volumes has a potential to improve postoperative outcomes and reduce the risk of pulmonary complications.¹ In addition, in experimental settings, hypercapnia could beneficially affect tissue perfusion and organ function.² The goal of our study was to assess the effects of the protective ventilation with low tidal volume (V_T) either alone or combined with moderate permissive hypercapnia in major abdominal surgery.

Methods

The study protocol and informed consent were approved by the Ethical Committee of the Northern State Medical University.

Sixty patients (28 females / 32 males, aged 54 (45–60) yrs) scheduled for major pancreatoduodenal and/or biliary surgery (mostly, pancreatic cancer) with expected duration exceeding 2 hrs were included into a single-centre prospective randomised study.

The patients were randomised to three groups receiving either routinely high V_T (10 mL/kg of predicted body weight (PBW): the HVT group, $n = 20$) or low V_T (6 mL/kg PBW: the LVT group, $n = 20$). An additional group with low V_T combined with moderate permissive hypercapnia (V_T 6 mL/kg PBW and $PaCO_2$ 45–55 mm Hg: the LVT+HC group, $n = 20$). In all groups PEEP of 4 cm H_2O was set. All interventions were performed using combined volatile (sevoflurane) and epidural anaesthesia. Haemodynamic parameters and gas exchange were registered during the surgery and up to 72 hrs of the postoperative period. We also analysed the incidence of the postoperative complications during the ICU stay.

Data are presented as median (25th–75th percentiles). Intergroup comparisons are made with Mann–Whitney U -test and χ^2 -test. A p value below 0.05 was regarded as statistically significant.

Results & Discussion

We did not find any significant baseline differences between the groups except for smoking incidence, that was higher in the HVT group (Table 1). The duration of postoperative ventilation was not different between the groups. The 28-Days mortality was 5% ($n = 3$) and the incidence of the postoperative complications was 40% ($n = 24$).

Table 1. The characteristics of the patients.

Data	HVT	LVT	LVT + HC
Age, yrs	64 (61–70)	64 (58–67)	0.62
Weight, kg	80 (71–94)	78 (70–86)	0.70
Gender (F / M)	8 / 12	11 / 9	9 / 11
Duration of surg., min	160 (135–250)	190 (138–234)	225 (180–264)
Duration of CMV, min	360 (270–525)	370 (265–499)	400 (295–473)
LOS ICU, hrs	44 (24–85)	43 (22–68)	45 (27–76)
LOS hospital, days	42 (25–51)	28 (21–38)	31 (26–41)
Smoking history, n (%)	6 (30)*	14 (70)	13 (65)
Complications, n (%)	11 (55)*	5 (25)	8 (40)

Data are presented as median (25th–75th percentiles), numbers or percentage. p values are calculated using Mann–Whitney U -test or Chi-square test. * $p < 0.05$ between the HVT and LVT groups.

Figure 1. The values of tidal volume and arterial PCO_2 in the groups at the beginning and end of the surgery.

Data are presented as median (25th–75th percentiles). p values are calculated using Mann–Whitney U -test for LVT vs. HVT for V_T and LVT vs. LVT+HC for $PaCO_2$. * — $p < 0.001$.

Figure 2. The values of PaO_2/FiO_2 ratio at 24 hrs.

Data are presented as median (25th–75th percentiles). p values are calculated using Mann–Whitney U -test comparing HVT and LVT groups; * — $p = 0.027$

Figure 3. The length of the hospital stay.

Data are presented as median (25th–75th percentiles). p values are calculated using Mann–Whitney U -test comparing HVT and LVT groups; * $p < 0.05$ compared with the LVT group.

Figure 4. The incidence of the postoperative complications in the study groups.

Data are presented as stacked numbers of the complications. p values are calculated using χ^2 -test between the HVT and the LVT groups; * — $p = 0.03$.

The values of V_T and $PaCO_2$ at the start and completion of the surgery for HVT, LVT, and LVT+HC groups are presented in Figure 1. Compared with the HVT group, PaO_2/FiO_2 ratio at 24 hrs postoperatively was higher in the LVT group: 333 (301–381) vs. 382 (349–423) mm Hg ($p = .027$), but not in the LVT+HC group (Figure 2). Notably, the transient improvement of the postoperative oxygenation was achieved despite the higher incidence of smoking in the LVT group compared with the HVT group (Table 1).

The length of hospital stay was significantly longer in the HVT group compared with the LVT group (Figure 3), that can be related to the higher incidence of the postoperative complications, particularly, atelectases (Figure 4). We found no differences in the incidence of the complications between the HVT and the LVT+HC groups.

By the end of the surgery, arterial lactate concentration was decreased in the LVT+HC group compared with the LVT group: 0.7 (0.5–1.0) vs. 1.5 (1.0–3.1) mmol/L, respectively ($p < .02$). However, arterial bicarbonate excess was worse in the LVT+HC group compared with the LVT group at 6 hrs postoperatively: -6.1 (-5.8 to -7.4) and -5.1 (-6.1 to -3.4) mmol/L, respectively ($p < .001$).

Conclusions

Preventive reduction of tidal volume in major pancreatoduodenal surgery results in improved postoperative oxygenation, reduced rate of complications, namely atelectases, and shortened length of the hospital stay.

The combination of low tidal volume and moderate permissive hypercapnia might exert some metabolic effects but does not add any substantial benefits to the outcome and organ function, and needs further studies.

Acknowledgements

We appreciate the assistance of Maria M. Sokolova, MD, Andrey A. Papko, MD, and Maria A. Feoktistova, MD.

References

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