Research article/Raziskovalni prispevek

INFLUENCE OF THORACIC EPIDURAL ANAESTHESIA ON INTESTINAL BLOOD SUPPLY

VPLIV TORAKALNE EPIDURALNE ANESTEZIJE NA PREKRVITEV PREBAVIL

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Key words *anaesthesia, epidural; intestine – blood supply; stress; sympathetic block*

Abstract

Background *To date research has demonstrated that the use of general anaesthesia in combination with thoracic epidural anaesthesia (TEA) protects the patient against surgical stress. There is disagreement, however, concerning the effect of TEA on intestinal blood supply. In order to determine the influence of TEA on intestinal blood flow, partial O_2 pressure (pO_2) and pH were determined in the portal blood that drains blood from intestine, just before liver resection. These values were compared with those measured in the superior caval vein which drains blood from the upper part of the body, region not directly affected by TEA.*

Methods *Forty patients included in our prospective randomized study were divided into two groups, i.e. a group of 20 patients given TEA in combination with general anaesthesia, and a group of 20 patients receiving only general anaesthesia. They were premedicated with midazolam 1.5–3.0 mg i. v. Immediately after introduction of an epidural catheter at T_{11}–T_{12}, 15 ml of 0.25% local anaesthetic bupivacain or 15 ml of 0.9% NaCl was injected into the thoracic epidural space in the TEA group and in the control group, respectively. Anaesthesia was initiated by intravenous opioid analgesic fentanyl 0.1–0.2 mg, thiopentone 4.0 mg/kg body weight, and muscle relaxant vecuronium 0.1 mg/kg body weight. The patients were intubated and controlled ventilation was started with a 45 to 55 per cent oxygen-air mixture with addition of the volatile agent isoflurane 0.8–1.5 vol %. Muscle relaxation was maintained with vecuronium at a dose of 2–4 mg i. v. Central venous pressure was maintained at a low normal limit, i.e. 6 ± 2 mmHg. Just before liver resection, blood samples were obtained from the portal vein and superior caval vein. Intestinal blood supply was evaluated by measuring pO_2 and pH in the portal vein, and the results were compared with the values obtained in the superior caval vein in each patient and in the two groups.*

Results *In both groups, pO_2 levels in the portal vein were significantly higher than those in the superior caval vein (TEA group: 7.8 kPa in the portal vein vs. 6.0 kPa in the superior caval vein; $p < 0.001$; control group: 7.5 kPa in the portal vein vs. 6.1 kPa in the superior caval vein; $p < 0.01$). No significant differences were found between the groups ($p > 0.05$). In both groups, portal venous pH was significantly higher than pH determined in the superior caval vein (TEA group: 7.41 in the portal vein vs. 7.39 in the superior caval vein; $p < 0.001$; control group: 7.41 in the portal vein vs. 7.39 in the superior caval vein; $p < 0.05$), yet they were within the range of normal. There was no statistically significant difference*

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between the groups ($p > 0.05$). In the TEA groups, a statistically significant negative correlation was found between the portal venous pH and pO_2 levels ($r = -4.7$) ($p < 0.05$). No such correlation was observed for the control group ($r = 0.058$; $p > 0.05$).

Conclusions *The observed negative correlation between pO_2 and pH levels in the portal blood of TEA group suggests that the use of TEA in combination with general anaesthesia with a central venous pressure of 6 ± 2 mmHg affords a more constant intestinal blood flow pattern than general anaesthesia alone.*

Ključne besede *anestezija, epiduralna; prebavila – prekrvitev; stres; simpatični blok*

Izvleček

Izhodišča *Številni raziskovalci so ugotavljali povezanost hipoksije črevesne sluznice med različnimi kirurškimi posegi z nastankom pooperacijskih zapletov. Zaradi anatomskih in fizioloških posebnosti je črevesna sluznica zelo občutljiva za hipoksijo, ki je z običajnimi meritvami, ki jih nadzorujemo med operacijo (krvni tlak, frekvenca srčnega utripa, urno izločanje seča), ne moremo zaznati. Vsako povečanje presnovne potrebe za kisik ali pa zmanjšana sposobnost za prenos kisika lahko vodi v hipoksijo in posledično acidozo črevesne sluznice. Predhodne raziskave so pokazale, da kombinacija splošne in torakalne epiduralne anestezije (TEA) zaščiti bolnika pred vplivi operacijskega stresa. O učinku TEA na prekrvitev črevesa pa so mnenja deljena. Da bi ugotovili vpliv TEA na prekrvitev črevesa, smo pri bolnikih tik pred začetkom jetrne resekcije v portalni krvi, kamor se izteka kri iz prebavil, določali delni tlak O_2 (pO_2) in pH. Te vrednosti smo primerjali z enakimi v krvi zgornje vene kave, kamor se izteka kri iz zgornjega dela telesa, kjer vpliv TEA ni bil neposredno izražen.*

Metode *V prospektivni, randomizirani raziskavi smo 40 bolnikov razdelili v dve skupini. V TEA skupini je 20 bolnikov dobiloTEA in splošno anestezijo in 20 bolnikov v kontrolni skupini samo splošno anestezijo. Za premedikacijo so bolniki dobili midazolam v odmerku 1,5–3,0 mg vensko. Vstavili smo jim epiduralni kateter v višini med 11. in 12. torakalnim vretencem; takoj po vstavitvi katetra smo bolnikom v TEA skupini vbrizgali v epiduralni prostor 15 ml 0,25% lokalnega anestetika bupivakaina, kontrolni skupini pa 15 ml 0,9% NaCl. Za uvod v anestezijo smo vsem bolnikom dali vensko 0,1–0,2 mg opioidnega analgetika fentanila, 4,0 mg/kg TT uspavala tiopentala in 0,1 mg/kg TT mišičnega relaksanta vekuronija, jih intubirali in nadzorovano predihavali z mešanico kisika in zraka v razmerju 45%:55% ob dodatku hlapnega anestetika izoflurana v koncentraciji 0,8–1,5 vol. %. Mišično relaksacijo smo vzdrževali z vekuronijem v odmerku 2–4 mg vensko. Osrednji venski tlak smo vzdrževali na spodnji meji normale (6 ± 2 mmHg). Tik pred začetkom jetrne resekcije smo odvzeli vzorce krvi iz vene porte in zgornje vene kave. Prekrvitev črevesa smo ocenjevali z vrednostmi pO_2 in pH v veni porte ter jih primerjali z enakimi vrednostmi iz zgornje vene kave pri istem bolniku ter med skupinama.*

Rezultati *V obeh skupinah je bila vrednost pO_2 v veni porte pomembno večja kot v zgornji veni kavi (TEA skupina pO_2 v veni porte 7,8 kPa, pO_2 v zgornji veni kavi 6,0 kPa [$p < 0,001$], kontrolna skupina pO_2 v veni porte 7,5 kPa, pO_2 v zgornji veni kavi 6,1 kPa [$p < 0,01$], med skupinama ni bilo pomembne razlike [$p > 0,05$]). Vrednost pH v veni porte je bila v obeh skupinah pomembno večja kot v zgornji veni kavi (TEA skupina pH v veni porte 7,41, pH v zgornji veni kavi 7,38 [$p < 0,001$], kontrolna skupina pH v veni porte 7,41, pH v zgornji veni kavi 7,39 [$p < 0,05$]), vendar v območju normalnih vrednosti. Med skupinama ni bilo statistično pomembne razlike ($p > 0,05$). Korelacija med pH in pO_2 v veni porte pri bolnikih iz TEA skupine je bila negativna ($r = -0,47$) in statistično pomembna ($p < 0,05$). V kontrolni skupini korelacije nismo ugotovili ($r = 0,058$; $p > 0,05$).*

Zaključki *V naši raziskavi smo pri vrednostih OVT 6 ± 2 mmHg ugotavljali nekoliko večje vrednosti pH in pO_2 v veni porte kot v zgornji veni kavi, neodvisno od vrste anestezije. V TEA skupini bolnikov smo ugotovili negativno korelacijo med pH in pO_2 v veni porte, ki je ni bilo v kontrolni skupini.*
Večje vrednosti pH in pO_2 v veni porte kot v zgornji veni kavi pri obeh skupinah si razlagamo s položajem bolnikov med operacijo.
Na negativni predznak korelacije med pH in pO_2 v veni porte je verjetno vplivala značilna anatomija črevesne sluznice s protitočnim načinom pretoka krvi v črevesni resici. V TEA skupini smo s TEA verjetno zmanjšali stresni odgovor in izločanje vazokonstriktornih hormonov, s simpatično blokado pa povzročili vazodilatacijo in enakomeren pretok krvi v

črevesu. Zaradi zmerno znižanega znotrajžilnega volumna krvi je prišlo do obvoda kisika v črevesu, ob tem pa še ni prišlo do acidoze črevesa, saj je bila vrednost pH portalne krvi še v normalnem območju.

V kontrolni skupini nismo našli korelacije med pH in pO_2 v portalni krvi. Pri vrednostih OVT 6 ± 2 mmHg so bila v črevesu neenakomerno razporejena področja s še ohranjenim in zmanjšanim pretokom krvi. Verjetno je obstajal obvod kisika v črevesu tudi pri kontrolni skupini bolnikov, vendar ga zaradi neenakomernosti pretoka z merjenimi vrednostmi pH in pO_2 nismo mogli ugotoviti.

Naši rezultati govorijo za obstoj obvoda kisika v črevesu pri vrednostih OVT 6 ± 2 mmHg, obenem pa tudi za bolj enakomeren pretok krvi in zaščitno vlogo TEA na črevo. Obstoj negativne korelacije med pO_2 in pH v portalni krvi pri bolnikih iz TEA skupine nakazuje, da TEA v kombinaciji s splošno anestezijo pri vrednostih osrednjega venskega tlaka 6 ± 2 mmHg ohranja enakomernejši pretok krvi v črevesu kot samo splošna anestezija.

Introduction

Numerous investigators have reported on the connection between intraoperative gut mucosal hypoxia and postoperative complications (1, 2). Because of its anatomical and physiological features, intestinal mucosa is very sensitive to hypoxia, which is not detectable by standard parameters monitored during surgery, such as blood pressure, heart rate and urine output (3). Increased metabolic oxygen requirements or reduced oxygen transfer may lead to hypoxia and the resulting intestinal mucosal acidosis, which occurs in 24–62 per cent of patients undergoing major surgery (1).

Gut mucosa acts as a barrier between the external and internal environment. Damage to intestinal mucosa facilitates the entrance of bacteria and endotoxins from the intestinal lumen into systemic circulation. Small amounts of endotoxins and bacteria translocated from the gut are effectively eliminated from the blood by the reticuloendothelial system (Kupffer cells). Under hypoxemic conditions, however, Kupffer cells fail to cope with the increased amount of bacteria and endotoxins, which may lead to systemic bacteremia and endotoxinemia, resulting in sepsis and multiple organ failure (4, 5).

Intraoperative stimulation of sympathetic nerves increases resistance in the intestinal arteries, hepatic artery and portal vein, which leads to a significant reduction of hepatic blood flow (6). Visceral organs are richly innervated by the autonomic nervous system and their response to surgical stress is more pronounced than in other organs (1, 3). The density of adrenergic receptors in the gut is higher than in other parts of the body. Splanchnic vasoconstriction (e. g. that associated with blood loss) is an early response to reduced oxygen delivery due to redistribution of blood flow to the heart and brain.

As a result, blood volume in the intestine is reduced to a much greater extent than in other organs. Studies on animals have demonstrated that bleeding leads to a fourfold increase in gut intravascular pressure compared to total intravascular pressure (3). In healthy volunteers, a reduction of blood volume by 15% induced a 40% reduction of intestinal blood volume, while blood pressure and heart rate remained unchanged (3).

Hepatic oxygen supply is compromised by massive bleeding, which is frequently associated with major liver resection. Blood loss and increase in stress hormone levels enhance the uptake of oxygen from the blood and induce hepatic arterial vasoconstriction and reduction in the amount of oxygen supplied to the liver by the portal vein and hepatic artery (7, 8).

Blockade induced by thoracic epidural anaesthesia (TEA) with local anaesthetics leads to a sympathetic block in the affected segments, and to a decreased release of vasoconstricting hormones secondary to attenuated systemic response to surgical stress (1). TEA block extending up to T3 inhibits stress response to afferent nocioceptive impulses travelling via somatic and sympathetic nerve fibres. Vagal afferent fibres cannot be blocked by TEA (9). Neither is it possible to prevent the effects that inflammatory mediators, released in the circulation during surgery, may exert on the hypothalamic-pituitary axis. A complete absence of surgical stress response is not desirable because of the role played by stress hormones in postoperative survival. Our aim is to prevent excessive stress response to surgery (10). The use of general anaesthesia in combination with TEA provides the best protection against harmful effects of surgical stress in patients undergoing major abdominal operations (11). Numerous studies have demonstrated the advantages of this anaesthetic technique in terms of lower need for blood transfusion, decreased postoperative complication rate and shorter ICU stay (12). There is disagreement, however, concerning the effect of TEA on the gut blood supply. Intestinal perfusion may be assessed by monitoring blood flow in the intestine. The majority of the techniques available, however, cannot be used intraoperatively. These include: measurement of intestinal mucosa permeability; pulsed ultrasonic Doppler measurement of blood flow through vessels; remission spectrophotometry; determination of metabolic parameters; assessment of intestinal perfusion by measuring oxygen saturation in the pulmonary artery and hepatic vein; calculation of portal-arterial pCO_2 gap, and correlation between gastric mucosal pH and portal blood oxygen saturation (4, 12–17). Gastric tonometry is the only technique used to date for intraoperative monitoring of intestinal perfusion (18).

The purpose of this study was to assess intestinal perfusion by determining portal venous pH and pO_2 levels in patients operated on under general anaesthesia in combination with TEA, and in patients receiving general anaesthesia alone.

Methods

This prospective randomized study included 40 patients undergoing elective major hepatic surgery for echinococcal cysts, benign and malignant tumors of the liver, and benign and malignant lesions of the biliary tract. The patients were ASA (American Association of Anesthesiologists) physical status I and II. They were informed about the purpose of the study and asked to sign a written consent. The study protocol was approved by the national medical ethics committee.

The patients were considered inelegible for the study if they had concomitant diseases affecting intestinal blood flow, such as diabetes, uncontrolled arterial hypertension, ischaemic heart disease and disturbances of cerebral blood flow, confirmed diagnosis of portal hypertension, elevated plasma bilirubin levels and vasculitis, and if their arterial pressure fell below 80 mmHg due to sympathetic blockade and had to be controlled by vasoconstrictors.

The patients were allocated to 2 groups, i. e. a group of 20 patients operated on under TEA plus general anaesthesia, and a control group of 20 patients receiving general anaesthesia alone. The patients were premedicated with midazolam in a dose of 1.5–3.0 mg i. v. Immediately after the introduction of an epidural catheter at T_{11}–T_{12}, a thoracic epidural injection of 15 ml of 0.25% local anaesthetic bupivacain was made in the TEA group and of 15 ml of 0.9% NaCl in the control group.

Anaesthesia was initiated by intravenous opioid analgesic fentanyl 0.1–0.2 mg, thipentone 4.0 mg/kg body weight, and muscle relaxant vecuronium 0.1 mg/kg body weight. The patients were intubated and started on controlled ventilation with an 45–55% oxygen-air mixture with addition of volatile anaesthetic isoflurane 0.8–1.5 vol%. Muscle relaxation was maintained with vecuronium in doses of 2 to 4 mg. Central venous pressure (CVP) was maintained at 6 ± 2 mmHg. In the TEA group, analgesia was provided with bupivacain via the inserted epidural catheter, and in the control group with fentanyl 0.1 mg, administered intravenously.

After anaesthesia was induced, a central venous catheter was introduced into the superior caval vein for CVP measurements and blood sampling. Next, a temperature-sensing urinary catheter was inserted, and a catheter was placed into the radial artery for continuous arterial blood pressure monitoring. Arterial pressure, arterial blood oxygen saturation, CVP, body core temperature, urine output and respiratory parameters, including respiration rate, tidal volume, end-inspiratory and end-expiratory pressure, end-expiratory partial CO_2 pressure and percent of oxygen in the breathing mixture were monitored continuously in all patients. In order to avoid circumstances that could have exerted additional effects on intestinal perfusion, we maintained normal temperature, normocapnia, normal arterial blood oxygen saturation rates and systolic pressure above 100 and below 140 mmHg throughout the blood sampling procedure. Just before liver resection, approximately 45 minutes after the induction of anaesthesia, 0.5 ml of blood was obtained from the portal vein and from the superior caval vein for pO_2 and pH determinations.

Excell and SPPS (Windows) were used for statistical analysis. For each patient, paired data from blood samples drawn in the portal vein and superior caval vein were analysed using the paired two-way Student's test. Non-parametric data were analysed with the Fischer exact test. The results are expressed by the mean value ± standard deviation (SD). The differences obtained were statistically significant at $p < 0.05$.

Results

Table 1 shows patient demographics, which did not differ significantly between the two groups ($p < 0.05$).

Table 1. *Patient demographics. Data are presented as a mean ± standard deviation (SD) and number of patients. Differences between the groups were not statistically significant.*

Razpr. 1. *Demografski podatki o bolnikih. Podatki so izraženi kot srednja vrednost ± standardna deviacija (SD) in število bolnikov. Razlike v vrednostih med skupinama niso bile statistično pomembne.*

Group Skupina	TEA group TEA skupina	Control group Kontrolna skupina
Number of patients Število bolnikov	20	20
Male/Female Moški/Ženske	15/5	12/8
Age (years) Starost (leta)	53 ± 11	54 ± 15
ASA* I/II	13/7	9/11
Body weight (kg) Telesna teža (kg)	79.3 ± 11.2	74.7 ± 10.7

*ASA: Classification of patients according to the criteria of American Society of Anesthesiologists. Physical status I/II patients have no or mild associated disease.

*ASA: Razvrstitev bolnikov po merilih Ameriškega združenja anesteziologov (American Society of Anesthesiologists). Bolniki razvrščeni v skupini I/II, so brez spremljajoče bolezni ali z zmerno izraženo spremljajočo boleznijo.

In both groups, portal venous pO_2 was significantly higher than pO_2 measured in the superior caval vein (pO_2 in the TEA group: 7.8 kPa in the portal vein vs. 6.0 kPa in the superior caval vein; $p < 0.001$; pO_2 in the control group: 7.5 kPa in the portal vein vs. 6.1 kPa in the superior caval vein; $p < 0.01$). There was no statistically significant difference between pO_2 measured in the portal venous blood and pO_2 determined in the superior caval venous blood ($p > 0.05$) (Figure 1). Similarly, both groups had significantly higher pH levels in the portal vein than in the superior caval vein (pH in the TEA group: 7.41 in the portal vein vs. 7.38

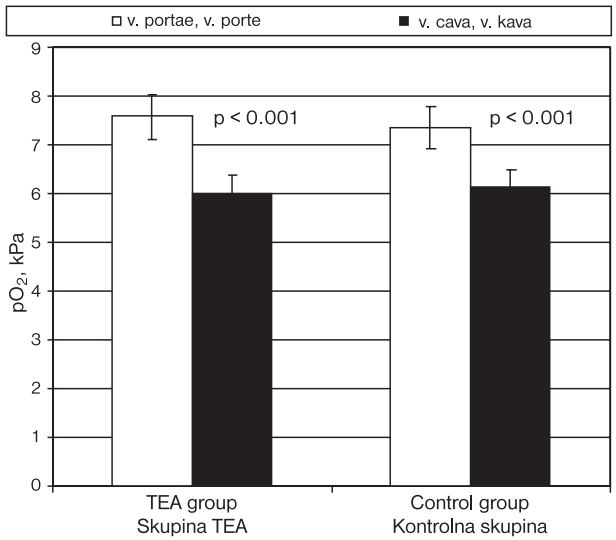

Figure 1. *Mean values and standard deviations of pO_2 in the portal vein and caval vein. In the TEA group and control group, pO_2 values in the portal vein were significantly greater than in the caval vein ($p < 0.001$). Differences between the groups were not statistically significant ($p > 0.05$).*

Sl. 1. *Srednje vrednosti in standardni odmiki pO_2 v veni porte in v veni kavi. V TEA in kontrolni skupini so bile vrednosti pO_2 v veni porte statistično pomembno večje kot v veni kavi ($p < 0,001$). Med skupinama se vrednosti pO_2 niso statistično pomembno razlikovale ($p > 0,05$).*

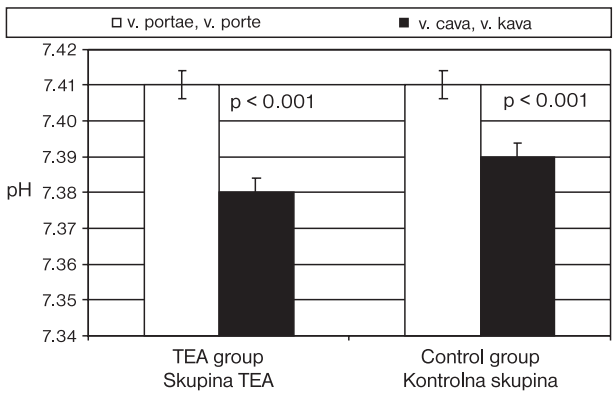

Figure 2. *Mean values and standard deviations of pH in the portal vein and caval vein. In the TEA group and control group, pH values in the portal vein were significantly greater than in the caval vein. Differences between the groups were not statistically significant (> 0.05).*

Sl. 2. *Srednje vrednosti in standardni odmiki vrednosti pH v veni porte in zgornji veni kavi. V TEA in kontrolni skupini so bile vrednosti pH v veni porte statistično pomembno večje kot v zgornji veni kavi. Med skupinama se vrednosti pH niso statistično pomembno razlikovale ($p > 0,05$).*

in the superior caval vein; $p < 0.001$; pH in the control group: 7.41 in the portal vein vs. 7.39 in the superior caval vein; $p < 0.05$ (Figure 2).

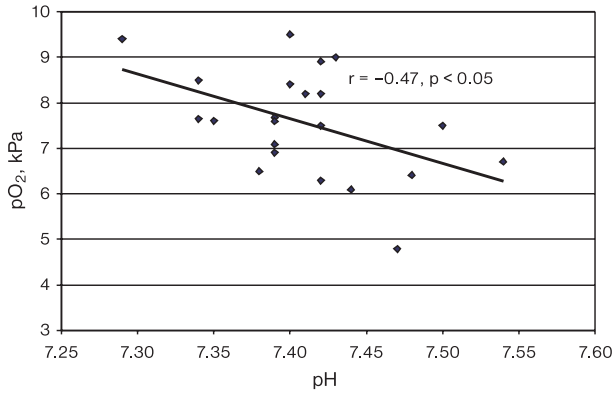

Figure 3. *Correlation between mean pH and pO_2 in the portal blood – TEA group ($r = –0.47$; $p < 0.05$).*

Sl. 3. *Korelacija med srednjimi vrednostmi pH in pO_2 v veni porte pri bolnikih iz TEA skupine ($r = –0,47$; $p < 0,05$).*

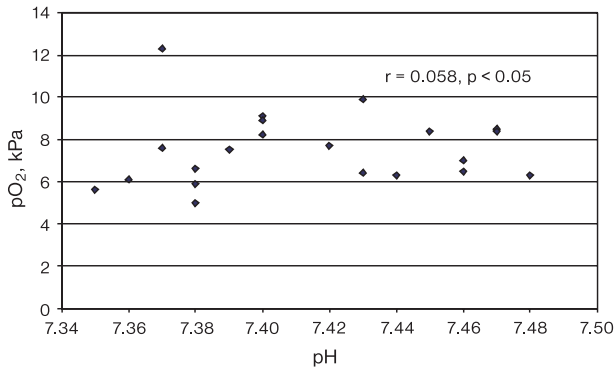

Figure 4. *Correlation between mean values of pH and pO_2 in vena portae in the control group patients ($r = 0.058$; $p > 0.05$).*

Sl. 4. *Korelacija med srednjimi vrednostmi pH in pO_2 v veni porte pri bolnikih iz kontrolne skupine ($r = 0,058$; $p > 0,05$).*

In the TEA group a statistically significant negative correlation was found between pH and pO_2 in the portal venous blood ($r = –0.47$; $p < 0.05$) (Figure 3). No such correlation was found for the control group ($r = –0.058$; $p > 0.05$) (Figure 4).

Discussion

The influence of TEA on the intestinal blood supply was studied mostly on animals. In the study by Sielenkamper et al., direct intravital microscopic examination revealed increased blood flow in the intestinal mucosa and villi of rats receiving TEA (16). Gretz et al. reported reduced blood flow in the intestine of dogs studied under the same conditions (19).

Using laser Doppler flowmetry, Johannson et al. demonstrated increased intestinal blood flow in patients undergoing colorectal surgery under TEA (20). Kainuma, et al., who measured oxygen haemoglobin saturation in the hepatic vein of patients undergoing

hepatectomy under general anaesthesia, reported on gut hypoxia resulting from decreased blood flow to the intestine and liver (21).

Vaisanen et al., and Mallinder et al. reported that intraoperative gastric tonometry failed to demonstrate the difference in gastric mucosal pH levels between patients undergoing abdominal surgery under TEA combined with general anaesthesia, and those operated on under general anaesthesia (22, 23). In both groups, pulmonary artery wedge pressure measurements were done to ensure adequate intraoperative fluid substitution and optimal haemodynamic conditions. TEA could not improve an already good intestinal blood supply achieved by optimal fluid substitution. Kapral et al. found significantly higher gastric mucosal pH levels in patients undergoing major abdominal surgery under general anaesthesia plus TEA as compared to patients operated on under general anaesthesia (24). Haemodynamic parameters were not monitored invasively, and it was not possible to detect early signs of fluid deficiency. Improvement in intestinal blood flow noted in the TEA group was attributed to sympatholytic effects of TEA, which prevented reflex vasoconstriction in the gut due to reduced circulating blood volume. The results of this study seem to confirm the gastric mucosal protective role of TEA in the presence of moderately reduced blood flow.

Portal venous pO_2 levels are influenced by several factors, including: local oxygen consumption, arterial oxygen delivery and presence of oxygen arteriolovenous shunts in the intestinal mucosa. Anaerobic metabolism due to inadequate intestinal perfusion can be assessed on the basis of pH levels determined in the portal venous blood. Tallgren et al. found correlation between gastric mucosal pH and portal venous pO_2 levels in the initial phase of liver transplantation when intestinal blood flow was still within normal range (15). During clamping of the hepatoduodenal ligament and intestinal hypoxia, however, there was no correlation between pO_2 in the portal vein and pH in the gut mucosa. Intestinal mucosal acidosis occurred despite relatively high portal blood oxygen saturation, which suggests that a correlation between intestinal mucosal pH and pO_2 in the portal venous blood indicates adequate intestinal perfusion. The adequacy of intestinal perfusion, however, cannot be inferred from portal blood oxygenation measurements (15, 24). Reduced intestinal blood flow may lead to counter current blood flow in the intestinal villi with the resulting hypoxia and acidosis of the tips of the villi in the presence of normal pO_2 levels in the portal venous blood (24).

In our study, intestinal blood flow was assessed by measuring portal venous pH and pO_2 levels immediately upon portal vein preparation for major liver resection. These levels were compared with the values in the superior caval venous blood, which is received from the upper body not directly affected by TEA. Circulatory filling pressure was determined by measuring CVP which was maintained at the lower normal level (6 ± 2 mmHg). In patients undergoing major liver resections, a moderately reduced intravascular blood volume is maintained in order to prevent retrograde bleeding from the resected hepatic surface.

In both groups, pH and pO_2 levels were significantly higher in the portal vein than in the caval vein ($p < 0.001$) regardless of the type of anaesthesia used. All values were within the range of normal. This findings suggest that blood flow to the gut was slightly better than that in the upper body, which may be attributed to the patient's position during liver resection (anti-Trendelenburg).

In contrast to the study by Tallgren et al., who found a positive correlation between gastric mucosal pH and portal venous O_2 in patients with normal blood pressure (15), we established a statistically significant negative correlation between these two parameters in our TEA group. The difference between the two observations may be due to different pH measurement sites, i. e. gastric mucosa in the study by Tallengren, and venous portal blood in this investigation. The result was most probably influenced by the characteristic anatomy of intestinal mucosa and the counter current blood flow pattern in the gut villi, which was not present in the gastric mucosa.

In the control group, no correlation between portal blood pH and pO_2 levels was found ($r = 0.058$; $p > 0.05$). In these patients, oscillations of stress hormone levels seem to have been more pronounced than in the TEA group. At a CVP of 6 ± 2 mmHg decreased blood perfusion was probably present in some gut areas. Because of variations of blood flow, no correlation was found between pO_2 and pH in the portal venous blood. We presume that in the TEA group, epidural anaesthesia attenuated surgical stress response and reduced release of vasoconstricting hormones. Sympathetic block induced vasodilatation and afforded constant blood flow to the gut. A moderately reduced intravascular blood volume led to oxygen shunts in the gut, but acidosis did not occur regarding normal portal venous pH levels. Most probably oxgen shunts were present in the control group too, yet the relationship between pH and pO_2 in the portal blood could not be determined because of variations in blood supply. This explains improvement in intestinal blood supply of patients receiving general anaesthesia plus TEA at a CVP of 6 ± 2 mmHg and normal systemic arterial blood pressure.

Conclusions

In our study, slightly higher pH and pO_2 levels were found in the portal vein than in the superior caval vein at CVP values of 6 ± 2 mmHg, regardless of the anaesthetic technique employed. These results seem to be attributable to the intraoperative position of the patient. In the TEA group but not in the control group, a negative correlation was found between pH and pO_2 levels in the portal vein. These findings are suggestive of the presence of intestinal oxygen shunts at CVP levels of 6 ± 2 mmHg, as well as of a more constant blood flow pattern and of gastric mucosal protective role of TEA.

References

1. Mythen MG, Webb AR. The role of gut mucosal hypoperfusion in the pathogenesis of post-operative organ dysfunction. Intens Care Med 1994; 20: 203–9.
2. Landow L, Phillips DA, Heard SO, Prevost D, Vandersalm TJ, Fink MP. Gastric tonometry and venous oximetry in cardiac surgery patients. Crit Care Med 1991; 19(10): 1226–33.
3. Lundgreen O. Physiology of the intestinal circulation. In: Marston A, Bukley GB, Fiddian-Green RG, Haglund UH, eds. Splanchnic ishemia and multiple organ failure. London: Edvard Arnold; 1989. p. 29–40.
4. Brinkmann A, Calzia E, Trager K, Rademacher P. Monitoring the hepato-splanchnic region in the critically ill patient. Intens Care Med 1998; 24: 542–56.
5. Fink MP. Why the GI tract is pivotal in trauma sepsis and MOF. Crit Ilness 1991; 6: 253–76.
6. Lautt WW, Legare DJ, d'Almeida MS. Adenosine as a putative regulator of hepatic arterial flow (the buffer response). Am J Physiol 1985; 248: H331–8.
7. Belghiti J, Noun R, Zante E, Ballet T, Sauvanet A. Portal triade clamping or hepatic vascular exclusion for major liver resection. Ann Surg 1996; 2: 155–61.
8. Bromage PR. 50 years on the wrong side of the reflex arc. Reg Anesth 1996; 21: 1–4.
9. Kehlet H. Epidural analgesia and the endocrine-metabolic response to surgery. Update and perspectives. Acta Anaesthesiol Scand 1984; 28: 1125–7.
10. Novak-Jankovič V, Paver-Eržen V, Bovill JG, Ihan A, Osredkar J. Effect of epidural and intravenous clonidine on the neuroendocrine and immune stress response in patients undergoing lung surgery. EJA 2000; 17: 50–6.
11. Liu S, Carpenter RL, Neal JM. Epidural anesthesia and analgesia. Their role in postoperative outcome. Anesthesiology 1995; 82: 1474–506.
12. Gelman S. Disturbances in hepatic blood flow during anesthesia and surgery. Arch Surg 1976; 111: 881–3.
13. Dahn MS, Lange P, Lobdell K, Hans B, Jacobs LA, Mitchell RA. Splanchnic and total body oxygen consumption differences in septic and injured patients. Surgery 1987; 101(1): 69–80.
14. Nagano K, Gelman S, Parks DA, Bradley EL Jr. Hepatic oxygen supply-uptake relationship and metabolism during anesthesia in miniature pigs. Anesthesiology 1990; 72(5): 902–10.
15. Tallgren M, Makisalo H, Hockerstedt K, Lindgren L. Hepatic and splanchnic oxygenation during liver transplantation. Crit Care Med 1999; 27(11): 2383–8.
16. Sielenkamper AW, Eicker K, Van Aken H. Thoracic epidural anesthesia increases mucosal perfusion of rats. Anesthesiology 2000; 93(3): 844–51.
17. Creteur J, De Backer D, Vincent JL. Does gastric tonometry monitor splanchnic perfusion? Crit Care Med 1999; 27(11): 2480–4.
18. Kehlet H. Modification of stress response to surgery by neural blockade: clinical implications. In: Cousins MJ, Bridenbough PQ, eds. Neural blockade in clinical anesthesia and management of pain. Philadelphia, PA: Lippincot-Raven; 1998. p. 129–75.
19. Gretz T, Andreen M, Irestedt L. Haemodynamics and oxygen consumption in the dog during high epidural block with special reference to the splanchnic region. Acta Anaesthesiol Scand 1983; 27: 211–7.
20. Johansson K, Ahn H, Lindhagen J, Tryselius U. Effect of epidural anaesthesia on intestinal blood flow. Br J Surg. 1988; 75(1): 73–6.
21. Kainuma M, Nakashima K, Sakuma I, Kawase M, Komatsu T, Shimada Y, et al. Hepatic venous hemoglobin oxygen saturation predicts liver dysfunction after hepatectomy. Anesthesiology 1992; 76(3): 379–86.
22. Vaisanen O, Parviainen I, Ruokonen E, Hippelainen M, Berg E, Hendolin H, et al. Epidural analgesia with bupivacaine does not improve splanchnic tissue perfusion after aortic reconstruction surgery. Br J Anaesth 1998; 81(6): 893–8.
23. Mallinder PA, Hall JE, Bergin FG, Royle P, Leaper DJ. A comparison of opiate- and epidural-induced alterations in splanchnic blood flow using intra-operative gastric tonometry. Anaesthesia 2000; 55(7): 659–65.
24. Kapral S, Gollman G, Bachmann D, Prohaska D, Likar R, Jandrasits O, Weinstabl C, et al. The effects of thoracic epidural anesthesia on intraoperative visceral perfusion and metabolism. Anesth Analg 1999; 88(2): 402–6.