Comparison of sodium nitroprusside- and esmolol-induced controlled hypotension for functional endoscopic sinus surgery

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The purpose of this study was to compare surgical conditions for functional endoscopic sinus surgery (FESS) under general anaesthesia during controlled induced hypotension, using either sodium nitroprusside (SNP) or esmolol. Twenty patients, assigned to receive either of the drugs as the primary hypotensive agent, were studied. The same surgeon, blinded to the hypotensive agent used and the haemodynamic variables, performed all the operations. The surgeon used a category scale (0–5) to assess surgical conditions – a value of 2–3 being ideal. Patients were positioned in 5° reverse Trendelenburg position and the mean arterial blood pressure (MABP) was reduced in steps of 5 mmHg. The anaesthetist prompted category scale estimations by the surgeon following a change in any of the haemodynamic variables. Average category scale (ACS) values were compared between the two groups for four data groups, i.e., MABP > 65 mmHg (mild), 60–64 mmHg, 55–59 mmHg and 50–54 mmHg. Pre-treatment MABP was 79.8 ± 10.4 mmHg in the SNP group and 76.1 ± 6.8 mmHg in the esmolol group. At mild SNP-induced hypotension, surgical conditions were poor (ACS = 3.63 ± 0.22; mean ± SEM), while in the esmolol group, ideal surgical conditions (ACS = 2.94 ± 0.34) were recorded at MABP > 65 mmHg. The combined effects of increased venous drainage due to the reverse Trendelenburg position, hypotension as well as capillary vasoconstriction due to unopposed alpha-adrenergic effect on the mucous membrane vasculature in the esmolol group (as opposed to vasodilatation in the SNP group) probably caused the superior surgical conditions.

Cette étude vise à comparer pendant la chirurgie endoscopique fonctionnelle des sinus sous anesthésie générale, les conditions chirurgicales obtenues avec l'hypotension délibérée réalisée soit avec du nitroprussiate de soude (SNP), soit avec de l'esmolol. Vingt patients sont assignés à recevoir l'un ou l'autre des agents hypotenseurs. Un seul chirurgien, ignorant l'agent utilisé et les paramètres hémodynamiques, effectue toutes les interventions. Le chirurgien cote les conditions chirurgicales sur une échellle de catégories de 0 à 5, les valeurs 2 et 3 étant jugées idéales. Les patients sont placés en Trendélenbourg renversé à 5° et la pression artérielle moyenne (PAM) est réduite par paliers de 5 mmHg. L'anesthésiste demande au chirurgien son évaluation sur l'échelle de catégorie à chaque changement de paramètre hémodynamique. Les valeurs moyennes de l'échelle de catégorie (ECM) sont comparées entre les deux groupes pour quatre sous-groupes de données, c-à-d, PAM > 65 mmHg (légère), 60–64 mmHg, 55–59 mmHg et 50–54 mmHg. Avant la perfusion, la PAM est 79,8 ± 10,4 mmHg dans le groupe SNP et 76,1 ± 6,8 mmHg dans le groupe esmolol. En l'hypotension légère au SNP, les conditions chirurgicales sont pauvres (ECM = 3,63 ± 0,22, moyenne ± SEM), alors que dans le groupe esmolol, les conditions chirurgicales idéales (ECM = 2,94 ± 0,34) surviennent avec une PAM > 65 mmHg. Les effets associés du drainage veineux en position de Trendélenbourg renversé, l'hypotension ainsi que la vasoconstriction capillaire causée par l'action alpha-adrénergique de l'esmolol sur les vaisseaux de la muqueuse dans ce groupe (contrairement à la vasodilatation dans le groupe SNP) sont, selon toutes probabilités, les causes des meilleures conditions chirurgicales.

Key words
ANAESTHETIC TECHNIQUES: hypotensive;
BLOOD PRESSURE: hypotension;
PHARMACOLOGY: sodium nitroprusside;
SYMPATHETIC NERVOUS SYSTEM: beta adrenergic blocker, esmolol.

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During functional endoscopic sinus surgery (FESS) for chronic sinusitis, otorhinolaryngologists use a rigid en-

doscope to perform this minimally invasive procedure. The aim of the operation is to restore the natural mucociliary clearance mechanism, drainage and aeration of the sinuses, whilst maintaining as much of the normal anatomy as possible.[1-3] Due to the promising clinical results achieved FESS is becoming a widely performed operation.

However, major complications like optic nerve damage, damage to the dura, meningitis and even death have been reported for FESS under general as well as local anaesthesia.[3-5] These usually result from impaired visibility due to excessive bleeding during surgery.[3] The threat of serious complications resulting from the poor visibility due to excessive bleeding in the surgical field, and the possibility of neurological damage associated with hypotensive anaesthesia,[6] make it important for anaesthetists to produce optimal surgical conditions. The aim should be to reduce BP as little as possible while providing the best possible surgical field.

This study compares the quality of the surgical field for FESS during general anaesthesia, using controlled hypotension induced with either the direct-acting vasodilator, sodium nitroprusside (SNP),[7] or the $beta_1$ antagonist, esmolol.[8] Previous cases performed in a pilot study under general anaesthesia and normotensive conditions produced unacceptable surgical conditions. The study did therefore not include a normotensive control group.

Methods

Following institutional ethical committee approval, 20 consenting ASA physical status I and II patients undergoing FESS were studied. Patients <16 yr were excluded as were patients preferring local anaesthesia and patients receiving cardiovascularly active drugs or drugs influencing blood coagulation (e.g., warferin, heparin, enoxiparin, NSAID or aspirin). Patients entering the study were randomly assigned to receive either SNP (Group I) or esmolol (Group II) as the primary hypotensive agent.

All patients received a standard premedication of midazolam 15 mg *po* one hour before induction of anaesthesia which was with propofol 2 $mg \cdot kg^{-1}$ injected into a large antecubital vein. Alcuronium 0.2 $mg \cdot kg^{-1}$ facilitated orotracheal intubation with a cuffed tracheal tube. The patients' lungs were mechanically ventilated to maintain an end-expiratory CO_2 tension of 35 ± 2 mmHg. Anaesthesia was maintained with 50% N_2O in oxygen and isoflurane, 1% insp. All patients received lactated Ringers' at approximately 3 $ml \cdot kg^{-1} \cdot hr^{-1}$ and were placed in a 5° reverse Trendelburg position to improve venous drainage.

Should tachycardia of more than 100 beats per minute develop, the patient received a single bolus of 500 ml lactated Ringers' and, if unresponsive, 100 μg fentanyl by single *iv* bolus injection. The patient would be eliminated from the study and appropriate measures taken if the tachycardia remained unresponsive to this management. Following induction of anaesthesia, patients in both groups received a topical application of a mixture of 4 ml tetracaine hydrochloride 2% and 1 ml epinephrine 1/1000 on well wrung-out cotton pledges to the nasal mucous membrane, applied for 10–15 min. After removal of the pledges, the surgeon infiltrated 0.5–1 ml lidocaine 1% with epinephrine 1/80,000 submucosally into the medial infundilar wall.

TABLE I Category scale for assessment of intra-operative surgical field

0	No bleeding.
1	Slight bleeding – no suctioning of blood required.
2	Slight bleeding – occasional suctioning required. Surgical field not threatened.
3	Slight bleeding – frequent suctioning required. Bleeding threatens surgical field a few seconds after suction is removed.
4	Moderate bleeding – frequent suctioning required. Bleeding threatens surgical field directly after suction is removed.
5	Severe bleeding – constant suctioning required. Bleeding appears faster than can be removed by suction. Surgical field severely threatened and surgery not possible.

Monitoring included a 20-gauge intra-arterial catheter for direct blood pressure measurement (Hewlett-Packard® monitor and transducer) with electronic integration to obtain the mean. The transducer was positioned at the level of the external auditory meatus to indicate cerebral perfusion pressure.

Steady-state anaesthesia was defined as a state of anaesthesia when no changes in haemodynamic variables took place for at least ten minutes prior to commencing administration of any hypotensive agents. When steady-state anaesthesia was obtained, the MABP was reduced in steps of approximately 5 mmHg. Sodium nitroprusside (Group I) was started at an infusion rate of 0.25 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and adjusted to maintain MABP within the target range. Esmolol (Group II) was initially administered by a bolus of 500 $\mu g \cdot kg^{-1} \cdot min^{-1}$ over a few minutes and then titrated at an infusion rate of 100–300 $\mu g \cdot kg^{-1} \cdot min^{-1}$ to maintain MABP within the target range. When the measured MABP changed, and remained at its new value for at least ten minutes, the surgeon estimated the quality of the operation field using a predefined category scale adapted from that of Fromme *et al.*[9] (Table I). The anaesthetist also prompted assessments at random intervals, when blood pressure and pulse rate remained unchanged, to verify previous assessments.

The same surgeon (JvdM) performed all the operations to ensure consistency in the estimation of the surgical

TABLE II Blood pressure, heart rate and category scale

MABP subgroup mmHg	*Syst BP mmHg*	*Diast BP mmHg*	*MABP mmHg*	*Heart rate bpm*	*Category scale*	*n*
Group I - SNP						
Pretreatment	112.2 (±14.06)	62.1 (±7.99)	79.8 (±10.43)	76.4 (±9.43)	- -	10
>65	96.75 (±5.4)	57.50 (±5.4)	69.75 (±3.56)	91.75 (±14.36)	3.63 (±0.22)	4
60–64	87.38 (±6.36)	48.88 (±2.67)	61.88 (±1.76)	87 (±12.08)	3.50 (±0.50)	8
55–59	78.88 (±5.73)	46.13 (±2.63)	56.75 (±1.39)	81.63 (±14.56)	3.31 (±0.56)	8
50–54	76.14 (±5.14)	39.81 (±2.99)	51.43 (±1.63)	81.76 (±14.24)	3.05 (±0.55)	22
Group II - esmolol						
Pretreatment	109.2 (±12.33)	58.7 (±6.68)	76.1 (±6.79)	78.1 (±6.31)	- -	10
>65	92.72 (±8.10)	61.13 (±4.59)	72.50 (±5.77)	84.38* (±13.09)	2.94* (±0.34)	8
60–64	84.36 (±6.81)	48.00 (±6.09)	62.73 (±2.00)	80.64* (±13.19)	2.82* (±0.65)	11
55–54	76.90 (±6.65)	46.30 (±2.85)	56.75 (±1.18)	68.90* (±5.30)	2.87* (±0.39)	20
50–54	71.00 (±3.60)	42.19 (±1.82)	52.38 (±1.53)	70.86* (±9.73)	2.48* (±0.36)	20

*Indicates comparison between Group I and II ($P > 0.05$).
Values are mean ± SDM.
n = Number of verified observations made following haemodynamic changes.

field. He was blinded to the hypotensive agent used, as well as to the monitor recording the haemodynamic variables. The QRS beep of the monitor was silenced so the surgeon could not judge the heart rate.

Ideal category scale values for surgical conditions were pre-determined to be between 2 and 3. Incremental reduction of the MABP by 5 mmHg continued until the surgeon reported a category scale of 3 or better, or until the MABP reached 50 mmHg. The MABP was then kept at that level by fine adjustments to the infusion rate of the hypotensive agent. Each estimation of the category scale by the surgeon following a change in haemodynamic variables was regarded as a new test. If the verifying observations made during unchanged haemodynamic conditions differed from the previous estimation made following a change in MABP, the latter would be disregarded.

For clarity, blood pressure recordings were analysed in batches of 5 mmHg. Hence four groups were compared, i.e., MABP > 65, 60–54, 55–59 and 50–54 mmHg. Data analyses were performed on the means and variance of these data groups. Data were collected electronically, stored by ARMS (Anaesthetic Record Management System, Paarl, RSA) and analysed with a commercially available statistical program (STST, Rockville, Maryland). Initially data were compared with ANOVA (Tukey) and homogenous groups defined with the multiple range test. Thereafter differences among groups were defined using the unpaired t test. Data were checked for normal differences and the Welch test was performed. A $P < 0.05$ was accepted as indicative of a significant difference.

Results

There were no demographic differences or differences in the pre-treatment blood pressures and heart rates in the patients in the two groups ($P >$ NS). The average category scale (ACS) for Group II (esmolol) was better than that of Group I (SNP) at all levels of MABP ($P < 0.05$) (Table II).

The ACS in Group II reached ideal levels (ACS 2.94 ± 0.34; mean ± SEM) early during the titration of esmolol, at MABP of >65 mmHg. During the early stages of the titration of SNP, however, and at the same level of MABP (MABP > 65 mmHg), the ACS for the quality of the surgical field was 3.63 ± 0.22 (mean ± SEM). At that ACS level frequent suctioning was required and bleeding threatened the surgical field directly after removing the suction (Table I).

Correlation between ACS and MABP showed r =

0.287 (SEE ± 0.56) and r^2 of 8.28% for the SNP group, and r = 0.311 (SEE ± 0.445) and r^2 of 9.70% for the esmolol group.

No patient was eliminated from the study due to uncontrollable tachycardia. There was no difference in the operating time between the two groups. Blood loss was minimal in both groups and no patient required blood transfusion or presented with excessive postoperative bleeding. None of the verifying observations during unchanged haemodynamics were discarded.

Discussion

Optimal surgical conditions for FESS were provided with minimal esmolol-induced hypotension (MABP > 65 mmHg). On the other hand, SNP-induced hypotension did not provide good quality surgical field until severe levels of hypotension were present (MABP 50–54 mmHg).

Operative bleeding results from cut vessels. It may be arterial, dependent on the MABP; capillary, which is dependent upon blood flow in the capillary bed; or venous and dependent on venous return and venous tone.

It has been reported that induction of mild hypotension by SNP titration causes generalised vasodilatation, reflex tachycardia and increased cardiac output.[7] Because the effect of SNP is directly on the vascular smooth muscle, catecholamines have little effect on the mucous membrane arterioles in the presence of SNP. The net result of vasodilatation and increased cardiac output is increased blood flow through the mucous membrane capillaries and increased bleeding during surgery on mucous membranes. Thus induction of mild hypotension with SNP will not be expected to improve surgical conditions when blood vessels of mucous membranes are cut. This supports the findings of Fromme *et al.*[9] who reported that mild SNP-induced hypotension did not improve the quality of the surgical field during orthognatic surgery. The surgical field reached near satisfactory levels after induction of severe hypotension with SNP in this study. This is in keeping with Chan *et al.*[10] who demonstrated improvement of the surgical field in SNP-induced hypotension following a 20% reduction in MABP.

Hypotension causes release of endogenous catecholamines and an increase of the sympathetic tone. The improved surgical field during esmolol-induced hypotension was probably attributable to vasoconstriction of the mucous membrane arterioles and pre-capillary sphincters that resulted from unopposed alpha-adrenergic effects of the endogenous catecholamines and the increased sympathetic tone. The beta-adrenergic effects of these vasoactive amines, as well as the effect of the increased sympathetic discharge to the heart, were blocked by esmolol. Patients in the esmolol group required less reduction of the blood pressure than those in the SNP group to provide satisfactory surgical fields.

We conclude that mild levels of esmolol-induced hypotension may provide optimal surgical conditions for FESS during general anaesthesia. It is suggested that hypotension caused by cardioselective beta-adrenergic antagonism resulted in increased sympathetic tone of the mucous membrane arterioles that exerted unopposed alpha-adrenergic effects on the mucous membrane vasculature, causing capillary vasoconstriction. Hypotension and improved venous return (due to the 5° reverse Trendelenburg position) were common to both groups. The arteriolar vasodilatation in the SNP group (as opposed to vasoconstriction in the esmolol group), may explain the relatively poor surgical conditions observed in the SNP group. The superior surgical conditions observed during esmolol-induced hypotension may be even more pronounced in other surgical settings to mucous membranes, skin and subcutaneous tissue where exogenous catecholamines or other vasoconstrictors are not administered.

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