BLOOD CONSERVATION IN CRANIO-MAXILLOFACIAL SURGERY

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Abstract

Cranio-maxillofacial surgery covers a wide spectrum, ranging from the repair of facial injuries and surgical oncology of the head and neck to the correction of developmental disorders of the face and the facial skeleton. Intraoperatively, there is routinely a turnover of blood in excess of 500 mL. Methods for the reduction of homologous blood transfusions have become an established part of anesthetic practice. Current practice includes acute normovolemic hemodilution (ANH), controlled moderate hypotension (CMH), cell salvage (CS), predeposit autologous blood donation (PBD) and the application of human recombinant erythropoietin (rh-EPO). This multimodal strategy was analyzed in detail for elective maxillofacial procedures.

Certain critical features of blood-saving measures have been investigated separately. It could be demonstrated that due to the bacterial contamination of wound blood, the washing step in the cell salvage procedure fails to clear the blood of bacteria, which leads to a significant increase in inflammatory mediators in the patient afterwards. Concerning administration of rh-EPO, intravenous iron significantly boosts the hematopoietic response and prevents iatrogenic iron depletion.

Rather than rigidly applying a standardized set of modalities, an appropriate and individualized approach to blood conservation measures should be applied to our patients.

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Introduction

Homologous as well as autologous blood products are subject to common errors, i.e. the release of incompatible blood, and contamination with bacterial organisms due to inadequate preservation or improper handling during storage and transport. There are inherent risks in homologous transfusions such as the transmission of bacteria, viruses, and protozoa, as well as alloimmunization and immunomodulation. Transfusion-induced immunosuppression may present acutely with an increased rate of postoperative infection and may also contribute to a higher rate of tumor recurrence.[1-4]

Current methods for the reduction of the number and frequency of homologous red cell transfusions have become an established part of anesthetic practice. The routine availability of procedures such as acute normovolemic hemodilution (ANH) during the induction of anesthesia, controlled moderate hypotension (CMH), cell salvage (CS) for intra- and postoperative autotransfusion, predeposit autologous blood donation (PBD) as well as the application of human recombinant erythropoietin (rh-EPO) in the preoperative period, has enabled sporadic efforts to be transformed into a coherent strategy.

Cranio-maxillofacial surgery covers a broad spectrum of pathologies in adults as well as children. It is a type of surgery that covers treatment of maxillofacial injuries, the surgical oncology of the head and neck, and the reconstruction of defects caused by both. Also of importance are the correction of developmental disorders of the face and the facial skeleton and the rehabilitation of the masticatory function. Because of the intense blood supply to the face, increased turnover of blood ($\geq$ 500 mL) is the rule intraoperatively. The analysis of the need for blood transfusions and the development of strategies aiming at the reduction of blood transfusions represents a main topic of research in this field. Taking into account the wide variety of pathologies and procedures in cranio-maxillofacial surgery, many of the questions concerning blood conservation measures are the same as in related surgical fields. In the study "Multimodal strategy for reduction of homologous transfusions in cranio-maxillofacial surgery", the authors tried to focus on the complexity of blood saving measures.[5] A representative subset, about 50% of the patients in the study cited above, is formed by patients undergoing elective osteotomies of both jaws.[6] These cases will be discussed later in more detail.

Some of the blood conservation measures being practiced are characterized by specific difficulties. Therefore, two examples of separate investigations will be discussed, one addressing the problem of cell salvage from a bacterially contaminated surgical field, and the other, looking into ways of improving the efficacy of the administration of rh-EPO.

Experimental Data

Orthognathic surgery represents a central issue of maxillofacial procedures.[5] Between 1994 and 1997, 127 patients who had undergone bimaxillary orthognathic procedures were included in a study aimed at a quality control assessment of blood conservation measures. Underlying pathologies consisted of dentoskeletal dysgnathias and pretreated cleft formations such as retromaxillism, pro- and retromandibulism and maxillomandibular asymmetries. Patients excluded from the study included: those suffering from craniofacial syndromes (i.e. otomandibular dysostosis, M. Crouzon and Apert, ectodermal dysplasia), patients with compromised general health or impaired hemostasis, and individuals requiring simultaneous bone grafts.

After obtaining consent from the patients, a standard protocol of blood conservation measures was used where the expected blood loss exceeded 500 mL:

- 6 weeks prior to surgery, preoperative autologous blood donation (PBD) in a authorized institution was organized.
- Since 1995, human recombinant erythropoietin was also used instead of the preoperative autologous blood donation (administration of 200 IU Eprex®/kg body mass

twice a week beginning 3 weeks prior to surgery up to an hematocrit of 50%). Iro supplementation was given.

- After induction of general anesthesia, acute normovolemic hemodilution (ANH) wa carried out with invasive monitoring. Depending on the patient's condition an hematocrit, an average of 9 mL blood/kg body mass was collected, and hydroxyethy starch was infused to maintain normovolemia,.
- Patients were positioned on the operating table in such a way that the surgical field wa situated above the level of the heart.
- There were no personnel changes in the anesthesiological or surgical staff, enabling th team members to maintain ongoing communication and a good working relationshi throughout the entire period.
- Intraoperatively, controlled moderate hypotension (CMH) was induced. CMH wa defined as a pharmacologically induced reduction of blood pressure to a mean arteria pressure of 60 mmHg. In patients with pre-existing hypertension, the mean arteria pressure was not reduced by more than 20% of the preoperative value.
- The blood collected from the surgical field intraoperatively was heparinized an collected in a cell salvage device reservoir. If sufficient blood was available, it could undergo the washing process, be centrifuged and be retransfused (Compact-A, Dideco™, Mirandola, Italy).

General anesthesia was induced in all patients using a standard, intravenous protocol. Intraoperative homeostasis was achieved and the following parameters were controlled: heart rate: 50-110/min; mean arterial pressure: 60-80 mmHg; central venous pressure: 2-12 mmHg; urine output ≥ 0.5-1.0 ml/kg body mass/h; pulse oxymetric O_2-saturation ≥ 97%; arterial pO_2 ≥13 kPa; arterial pCO_2: 4.5-5.5 kPa; hematocrit ≥20%; body temperature (rectally): 35.5-36.5°C.

Blood loss was initially treated with an infusion of crystalloid and colloidal solutions, and the hematocrit was closely controlled, according to the patient's general condition, with a lower value tolerated to a level of about 20%. The ANH blood collected was retransfused at the end of surgery. If needed, the CS erythrocyte suspension was retransfused prior to that.

Under control and in comparison with preoperatively defined values, homeostatic conditions could be obtained intraoperatively. No unexpected values were recorded for either cardiac (HR, SAP, MAP, DAP) or pulmonary parameters (PaO_2, $PaCO_2$) or temperature. Because of surgical blood loss, changes in the hematocrit in time were observed (Table).

In all patients included in the study, controlled moderate hypotension was induced. Acute normovolemic hypotension was carried out in 77.2% of the cases, whereas cell salvage was performed in 48.8%. Preoperatively donated blood units were available for 57.5% of the patients, and 15.7% received rh-EPO preoperatively. None of the 127 patients needed homologous blood intraoperatively.

Discussion

Bimaxillary osteotomies with increased blood loss have required blood transfusions on a regular basis.[7-10] However, of the 127 patients included in our study, who all underwent bimaxillary osteotomies, none received banked blood intraoperatively.[6]

Controlled moderate hypotension (CMH) with a mean arterial pressure aimed at 60 mmHg was achieved in all 127 patients under continuous invasive pressure monitoring. The median value of mean arterial pressure was 68 mmHg. In a number of studies, a decrease of intraoperative blood loss by CMH could be demonstrated.[11-14] In the context of blood conservation measures, the avoidance of systolic blood pressure peaks and the lowering of diastolic pressure values contribute to reduced intraoperative loss of blood.

Surgical experience with **a straightforward, atraumatic approach** should play an important role in these time-consuming operations. From the commencement of surgery, special attention should be paid to **the correct positioning** of the patient on the operating table. In consultation with the surgeon, the surgical field should always be kept above the level of the heart.

Of great importance is **maintaining intraoperative homeostasis**. This involves stabilizing the cardiovascular, pulmonary and laboratory parameters. Body temperature and fluid balance should also be kept under control. As shown in the table, it was possible to maintain intraoperative homeostasis. For example, all 127 patients demonstrated normothermia intraoperatively. Hypothermia can lead to hemorrhagic diathesis and increased blood loss.[15,16] Concerning blood pressure values, besides controlling the mean arterial pressure, both systolic peaks and low diastolic values should be avoided, both of which can cause further blood loss. Partial pressure of O_2 and CO_2 were monitored precisely, as increased CO_2 levels can induce vasodilatation, leading to increased blood loss.

In 62 of the 127 patients, the shed blood volume collected was sufficient to be processed by a cell salvage system (CS) and be retransfused afterwards. Some authors argue that washed and centrifuged shed blood aspirated from a wound area is contaminated with bacteria and thus represents a contraindication for retransfusion.[17] However, in the literature, the cell saver for transoral procedures has been recommended and has been routinely used for some years.[18]

A study has been carried out focusing on the problem of postoperative hyperthermia in cell salvage patients. It could be demonstrated that CS erythrocyte suspensions contain bacteria that are normally present in the oral flora. Thus the increases in cytokine concentrations in these patients following CS retransfusion are most likely due to the bacterial contamination of wound blood that the washing step in the cell saving procedure has failed to clear of bacteria. The fact that oral bacteria were found in the blood is related to the surgical procedure performed in the oral cavity. Therefore transoral cell salvage should be avoided.[19]

A preoperative autologous blood donation (PBD) was arranged for 73 of the 127 patients. Among these, 15 received their own blood retransfused intraoperatively. Without any doubt, the safety margin for these patients was increased. In our routine, retransfusion of donated blood occurred only after all other options were exhausted. This is because the risks inherent in this method – i.e. contamination, overstorage and accidental exchange – are the same as with banked blood, except that the source is known. However, one should avoid rejecting well-established blood conservation methods intraoperatively as this would lead to a clearly increased percentage of transfusion of homologous blood.[5] As with the administration of banked blood, donation of autologous blood needs careful decision-making.

Since 1995, patients have received during their **preoperative course recombinant human erythropoietin** (rh-EPO). To build up the patient's blood mass by means of a drug-induced increase in hematocrit, preoperative autologous blood donation was avoided.[20] Using the hospital's infrastructure, attendance for rh-EPO application only took a few minutes. In our experience, patients felt this procedure to be more agreeable than blood donation and less exhausting because of reduced invasiveness and undiminished energy.

Concerning the substitution of iron in addition to rh-EPO, the following clinical trial was carried out: 12 adults with normal hemoglobin and iron status due for elective surgery were randomized to rh-EPO 200 U/kg body weight subcutaneously twice weekly combined with either iron sucrose 200 mg intravenously twice weekly or iron sulfate 160 mg/day orally, for 3 weeks preoperatively. Efficacy was measured by the increases over baseline in hemoglobin, reticulocyte count and ferritin recorded 3 days before surgery. Preoperative reticulocyte count and ferritin were significantly higher with intravenous iron, while the only significant intragroup increases in hemoglobin between time points also occurred in this group. Intravenous iron significantly boosts the hematopoietic response to rh-EPO and prevents iatrogenic iron depletion in otherwise healthy candidates for elective surgery.[21]

After induction of general anesthesia in 98 out of 127 patients, autologous blood was collected by means of acute normovolemic hemodilution (ANH). In all patients, the retransfusion of the high quality erythrocytes as well of the intact clotting factors was carried out at the end of the surgical procedure. The main question concerning ANH is the extent of hemodilution anemia. This is influenced by the patient's concomitant diseases. A consensus on hematocrit values requiring transfusion has not been reached. Common sense tells us that maintaining normovolemia is a basic condition for the acceptance of low hematocrit values.[22] For this reason, especially in the cardiopulmonary compromised patient, in addition to close monitoring with laboratory tests, adequate, continuous invasive monitoring should be installed.

In contrast to results cited in literature,[23] the surgeons involved in this study strongly suspect ANH of being responsible for increased intra- and postoperative face swelling. In terms of cost-effectiveness, ANH seems to be inferior to CMH.[24] ANH is still a valuable blood saving measure, but should not be regarded as first choice.

Conclusion

As example, it could be demonstrated that in bimaxillary orthognathic surgery, transfusion of homologous blood was not necessary when a framework of different blood saving methods was applied. These procedures result in blood loss that even in a worst-case scenario does not exceed a volume of 3000 mL. In the study protocol, it was not the intention to apply a rigid set of modalities, but to offer – within the framework of given parameters – an appropriate and individualized approach to blood conservation measures. This is of special importance for quality control and maintaining normal physiological circumstances. The transfer of these results from orthognathic surgery to other maxillofacial or comparable procedures should be possible.

However, after conducting some studies and analyses in this field, the authors propose simplifying clinical routine according to the following approach. Close, open-minded collaboration between experienced surgeons and anesthesiologists is the first prerequisite.

Preoperatively, administration of rh-EPO in combination with intravenous iron helps to avoid autologous blood donation. Intraoperatively, CMH, careful attention to homeostasis, positioning the surgical field above the level of the heart and the acceptance of low hematocrit values should all be considered as state-of-the-art methods. These findings may also be applied to similar procedures.

Table. Patient Characteristics and Intraoperative Measurements

	Patients undergoing bimaxillary osteotomies (n = 127) median (range)
age (years)	**19** (15-53)
body weight (kg)	**60** (40-113)
body height (cm)	**169** (147-195)
gender (male/ female)	48/ 79
ASA I/ II	114/ 13
preoperative hematocrit (%)	**39.6** (28.0-55.7)
duration of surgery (min.)	**402** (140-630)
intraoperative blood loss (mL)	**1200** (500-3000)
intraoperative hematocrit (%)	**30.5** (20.5-43.0)
intraoperative body temperature (^{o}C, rectal)	**36.4** (35.4-37.2)
intraoperative MAP (mmHg)	**68** (55-80)
intraoperative SAP (mmHg)	**100** (85-120)
intraoperative DAP (mmHg)	**53** (40-65)
intraoperative heart rate (/min.)	**80** (60-100)
intraoperative arterial O_2 partial pressure (kPa)	**24.8** (12.0-46.5)
intraoperative arterial CO_2 partial pressure (kPa)	**4.5** (3.8-5.3)

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