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Quantitative analysis of facial soft tissue perfusion during hypotensive anesthesia using laser-assisted indocyanine green fluorescence angiography

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Abstract. The aim of this study was to quantitatively evaluate the efficacy of induced hypotensive anesthesia in decreasing facial soft tissue perfusion during orthognathic surgery using laser-assisted indocyanine green fluorescence angiography. This retrospective study involved the evaluation of 16 patients who underwent orthognathic surgery. Data collection included facial tissue perfusion of the bilateral cheeks and chin at normotension and with pharmacologically induced hypotensive anesthesia. There were statistically significant differences in the facial tissue perfusion at normal and depressed levels of blood pressure ($P < 0.001$). This study used an objective measure to demonstrate the long-standing belief that hypotensive anesthesia is efficacious in reducing tissue perfusion in the surgical field. The data suggest that pharmacologically depressing the level of mean arterial pressure by 18% may result in a 41–52% decrease in facial soft tissue perfusion. This study reports a novel method of quantitative analysis.

Key words: perfusion; hypotensive; anesthesia; quantitative; spy; indocyanine; green; fluorescence; angiography; orthognathic.

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Hypotensive anesthesia is a method by which blood pressure is intentionally decreased in a predictable manner in order to reduce intraoperative blood loss and improve the quality of surgical field visualization[1–17]. In theory, its efficacy lies in reducing tissue perfusion to the surgical site. It was initially described by Gardner, who in 1946 used arteriotomy to reduce blood pressure during surgery[18]. Since then various techniques for inducing hypotension during surgery have been

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used in orthopedic and neurosurgical procedures. Hypotensive anesthesia was first described with respect to maxillofacial surgery in 1950 by Enderby[19]. In 1976, Schaberg et al. reported the first clinical study evaluating the use of hypotensive anesthesia to reduce blood loss in maxillofacial surgery[20].

Orthognathic surgery is well established as the main modality of treatment for the correction of dentofacial deformities, with predictable outcomes and a high safety profile. Bimaxillary osteotomies (double-jaw surgery) are often necessary to achieve the desired results[21]. Due to the complex vascularity of the maxillofacial region, considerable bleeding from the soft and hard tissues may occur, resulting in suboptimal visualization and the potential need for blood transfusion[22–29]. Increasing awareness of the inherent risks associated with allogeneic blood transfusion has led to the development of strategies for reducing intraoperative blood loss[30–32]. Numerous clinical trials involving patients undergoing orthognathic surgery have demonstrated the benefits of hypotensive anesthesia.

Previous studies demonstrating the benefits of hypotensive anesthesia have reported estimated values and categorical variables, including estimated intraoperative blood loss, blood transfusion requirements, duration of surgery, and quality of surgical field visualization[1–9]. However, tissue perfusion during surgery has not been measured directly to correlate with blood pressure. This study was designed to investigate the quantitative effects of induced hypotensive anesthesia on perfusion of the facial soft tissues using laser-assisted indocyanine green fluorescence angiography (SPY Elite System) technology.

The SPY Intraoperative Perfusion Assessment System (distributed in North America by LifeCell Corp., Branchburg, NJ, USA; manufactured by Novadaq Technologies Inc., Richmond, British Columbia, Canada) was introduced to the United States market in 2005. The system utilizes laser-generated and near-infrared light, and indocyanine green (ICG) as the imaging agent. ICG has a well-established safety profile; it is metabolized in the liver, excreted in bile, and has a half-life of about 2.5 min. After intravascular injection, ICG binds plasma proteins in the blood. The laser light source illuminates the surgical field with a near-infrared wavelength (around 780 nm) below the threshold for tissue damage that does not require the use of protective eyewear or other safety equipment. This illumination causes fluorescence of ICG. The camera captures the fluorescing ICG with perfusion of the vascular system. The technology has received clearance from the US Food and Drug Administration for use in cardiovascular procedures, plastic, micro- and reconstructive surgical procedures, organ transplantation, and gastrointestinal surgical procedures[33–35].

Materials and methods

Patients

This study included 16 patients who underwent orthognathic surgery with induced hypotensive anesthesia and intraoperative perfusion imaging using laser-assisted ICG fluorescence angiography. Patient participation in this study was approved by the Institutional Review Board of the University of Florida College of Medicine in Jacksonville. Seven male and nine female patients were included in the sample. The mean age of the patient sample was 29.1 years, with a range of 15.4 to 52.1 years. All patients were classified as American Society of Anesthesiologists (ASA) physical status class 1 or 2 and had no cardiovascular, cerebrovascular, renal, or hepatic diseases. Three patients reported tobacco abuse. One patient had a history significant for hemifacial microsomia. Two patients had a history significant for cleft lip and palate with multiple surgeries for repair. One patient had a history significant for panfacial trauma with subsequent completion of open reduction and internal fixation procedures for the treatment of Le Fort, zygomaticomaxillary complex, and nasal bone fractures.

The orthognathic surgical procedures performed were the standardized Le Fort I osteotomy (one or two pieces) or Le Fort I combined with standardized mandibular bilateral sagittal split osteotomies. All patient subjects underwent the Le Fort I osteotomy, while 11 of the 16 patients underwent bimaxillary osteotomies. Additional procedures such as genioplasty (two patients) or placement of alloplastic chin (three patients) and/or tear trough (two patients) implants were also completed. All surgical procedures were performed by the same group of surgeons, and all hypotensive general anesthesia procedures were completed by the same group of anesthesiologists. The demographic data reviewed included patient age, past medical history, surgical history, history of facial trauma, and history of non-surgical procedures.

Study design

All patient subjects acted as their own controls: perfusion data associated with normotensive blood pressure prior to the commencement of surgical procedures and perfusion data associated with hypotensive anesthesia at the time of downfracture of the maxillary bone were recorded. Randomization principles did not apply to this study. All patients were placed in the supine position on the operating table, with a standardized foam head support and negligible head elevation. Lidocaine 1% with epinephrine 1:100,000 was administered submucosally to the surgical sites at the beginning of the procedure, following ICG fluorescence angiography perfusion imaging.

Anesthesia protocol

A standardized anesthesia technique was used, consisting of premedication with intravenous midazolam prior to the induction of anesthesia. Induction was completed with intravenous lidocaine, fentanyl, propofol, and a neuromuscular blocking agent. All patients were intubated via nasoendotracheal route. General anesthesia was maintained by continuous inhalation of sevoflurane and intermittent boluses of fentanyl and rocuronium. Induced hypotension was achieved via titrated inhalation of sevoflurane; beta-adrenergic antagonists, calcium channel blockers, and propofol (for its indirect vasodilatory effect) were administered as needed. Levels of hypotension were initiated following the gathering of perfusion imaging data at the time of induction and intubation and were continued through to the end of osteosynthesis. Blood pressure was recorded non-invasively every 5 min during the procedures. Keeping within the standard of care, the target hypotensive mean arterial pressure (MAP) was between 50 and 65 mmHg, as described in previous works[5,10,12,13,15,17]. Intraoperative monitoring consisted of electrocardiography and standard mechanical ventilation parameters, including end-tidal carbon dioxide, pulse oximetry, temperature, and blood pressure.

Indocyanine green fluorescence angiography imaging

SPY Intraoperative Perfusion Assessment System technology was used to capture images depicting blood perfusion to the maxilla prior to the initial surgical incision (preoperative) and again following downfracture and mobilization of the maxilla