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ICG-angiography for rectal advancement flap in patients with anal fistulas

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ABSTRACT *AIM: to evaluate ICG-angiography for the fistula advancement flap.*
PATIENTS AND METHODS: a prospective cohort study included 9 patients (6 males) with trans- and extrasphincteric anal fistulas. All patients underwent surgery with advancement flap and intraoperative ICG-angiography with video recordings.
RESULTS: three types of rectal vascular network were identified, distributed by 3, 4 and 5 distal branches of the rectal arteries. Detailed chronometry showed that the time of onset of the arterial phase did not differ significantly, regardless of the advancement flap's width. However, the following changes in the venous outflow were identified: at full-thickness flap's width of 1/3 of the rectal circumference, a slight lengthening of the venous outflow was detected (increase of the average time for onset of the maximum fluorescence phase to 61.5 vs the unaffected rectum (58.2 sec.). At full-thickness flap's width of 1/4 of the rectal circumference — significant ($p < 0.05$) increase of the mean time for onset of the maximal fluorescence phase to 77.6 sec., that is, in 1.26 times compared to patients with flap's width of 1/3 of the rectal circumference.
CONCLUSION: ICG-angiography visualize the vessels of the rectum intraoperatively, and it helps to find optimal margins of advancement flap.

KEYWORDS: *pararectal fistula, ICG-angiography, rectum's angioarchitectonics*

CONFLICTS OF INTEREST: *The authors declare no conflicts of interest*

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INTRODUCTION

In common clinical proctological practice, one of the most common conditions is anal fistulas with a prevalence 10–12 cases per 100 thousand people and up to 30–45% in the total structure of coloproctological diseases [1,2]. In most cases, fistulas are formed as an outcome of perianal abscess in patients up to 50 years, more often in men [3].
As for surgery, despite the active use of modern sphincter-preserving procedures (ligation of the fistula in the intersphincteric space (*LIFT*), laser ablation of the fistula (*FiLac*), video-assisted treatment of anal fistulas using a fistuloscope (*VAAFT*), etc.), the effectiveness of such minimally invasive techniques remains controversial. For example, when performing the *LIFT*, the rate of successful outcomes is 40–80%, and the anal incontinence is 1.5–6.0% of cases [4–6]. The 'surgical success' of *FiLaC*, including patients with recurrent fistulas, is 69.7%, and the rate of anal incontinence is 1% [7]. According to another meta-analysis, the rate of effective use of this technique reaches only 63% [8].
The most studied 'gold standard' of surgery for complex trans- and extra-sphincter fistulas

remains excision of the anal fistula with the rectal advancement flap.

This technique provides long-term closure of the fistula in up to 87% of cases with anal incontinence of 7.0–20.4%, and the risk of recurrence of 7.4% [4,5,9]. When performing such procedures, of course, the key points are the quality of flap formation with adequate blood supply and closure without tissue tension.

Intraoperative fluorescent angiography with indocyanine green (ICG) is a method for evaluating tissue perfusion and vascular network. Indocyanine Green is a tricarbocyanine compound soluble in water, rapidly and actively binds to plasma proteins and has a favorable safety profile, which makes it promising for use in angiography [10–12]. This fluorescent agent has already been successfully used in colorectal surgery, upper gastrointestinal surgery, transplantation, oncology and is considered as the main method for ensuring the safety of these procedures [13,14]. However, scientific studies on intraoperative ICG for the blood supply of the rectal advancement flap for anal fistulas are rare in the literature. In particular, according to PubMed, only 1 article was published (Primo-Romaguera, V. et al, 2023), which described a single case of the use of ICG angiography in plastic surgery with an advancement flap [15].

AIM

to assess the feasibility of ICG for rectal advancement flap in patients with anal fistulas.

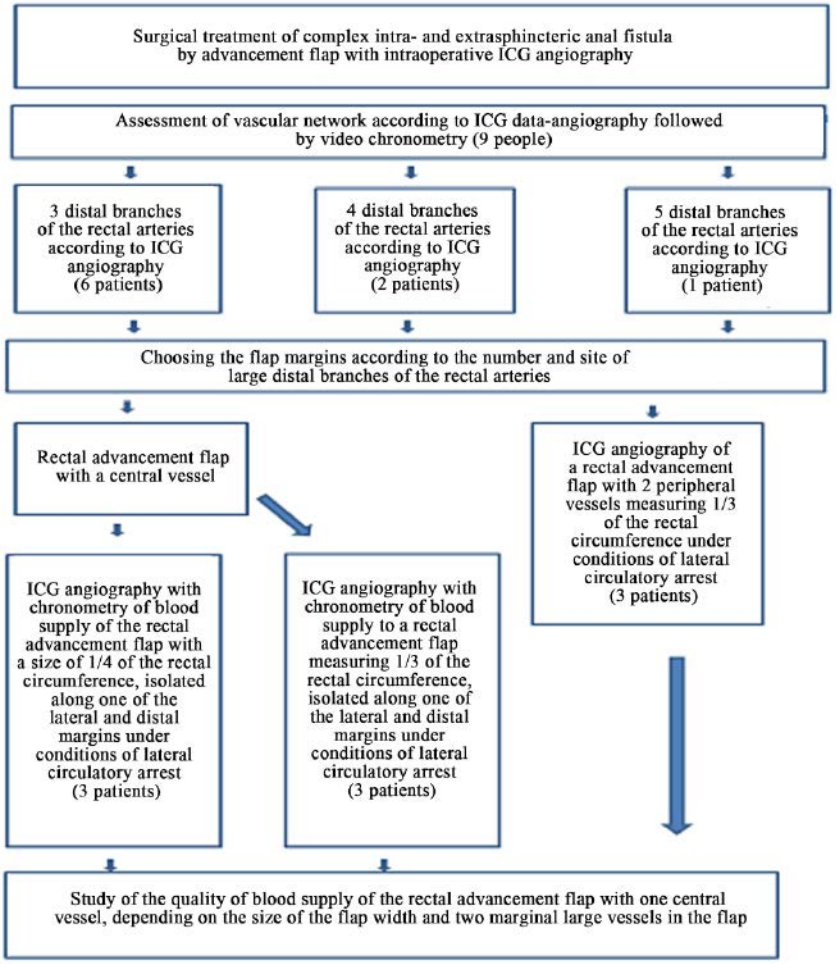

Figure 1. *Study design*

PATIENTS AND METHODS

A prospective cohort study of intraoperative ICG and its video recordings included 9patients :6 (66.7%) males, aged 21–69 years.

The study was approved by the local independent Ethics Committee, and all the patients signed consent to undergo surgery under conditions of intraoperative angiography using intravenous fluorescent stain — ICG. The criteria for inclusion of patients in the study were: trans- and extrasphincteric anal fistulas of varying complexity, cryptoglandular origin, no surgery before, signed consent to intraoperative ICG angiography.

Exclusion criteria were: post-radiation, congenital fistulas, fistulas in tumor diseases, fistulas of tuberculous and actinomycotic etiology, fistulas in Crohn's disease and ulcerative colitis, as well as colorectal surgery in the history.

The overall design of the study is shown in Figure 1. In the preoperative period, all the patients underwent checkup in accordance with National Clinical Guidelines for the treatment of anal fistulas [16], including anoscopy, video colonoscopy, ultrasound, pelvic MRI, fistulography.

Surgery for the anal fistula with the rectal advancement flap ICG angiography step by step

All procedures were performed using Karl Storz IMAGE1 S™ H3-LINK (TC 300) + CONNECT™ (TC 200) equipment (Germany) under general anesthesia lithotomy position, using a standard set of surgical instruments used in performing perineal surgery. To stain the fistula track, a solution of methylene blue was used, which was diluted immediately before administration in a 1:1 ratio with a 3% solution of hydrogen peroxide.

The first stage, after installing a 23-mm beak-shaped anoscope with a 1/2-circle transverse cutout, was to stain the fistula track with the determination of the internal fistula opening, then ICG was injected into the peripheral vein at a dose of 0.25 mg/kg in order to study the vascular network of the rectum and select the flap margins being formed. After the injection of ICG into the peripheral vein, the arterial phase begins first, and its end was accompanied by the onset of the venous phase and, accordingly, staining of the veins and maximal fluorescence (Fig. 2–4).

Taking into account the number and site of the distal branches of the rectal arteries, the margins of the 'cutting out' of the flap were marked so that patients with 3 distal branches of the rectal arteries had one vessel in the center of the flap, and patients with 4 and 5 branches had two adjacent

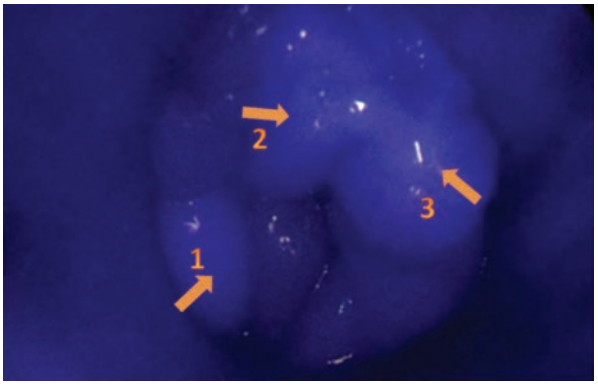

Figure 2. *Rectal vascular network with 3 distal branches of the rectal arteries (using ICG-angiography)*

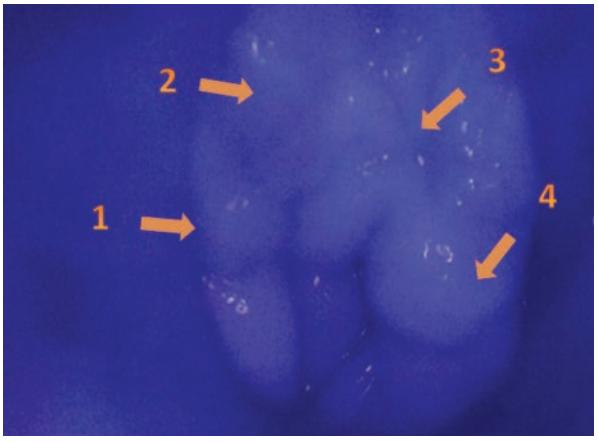

Figure 3. *Rectal vascular network with 4 distal branches of the rectal arteries (using ICG-angiography)*

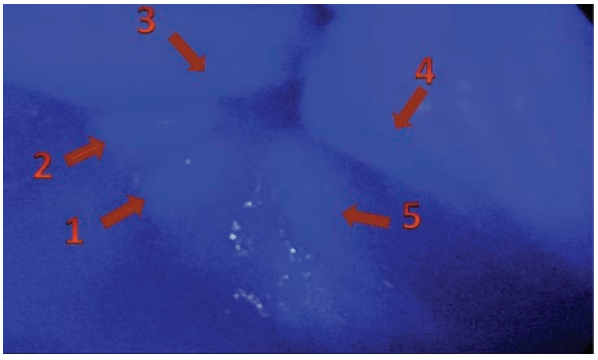

Figure 4. *Rectal vascular network with 5 distal branches of the rectal arteries (using ICG-angiography)*

vessels in the flap being formed along the periphery. The next step was to excise the external opening of the fistula track with an ellipsoidal incision to the intra-sphincter part of the fistula passage, followed by *FiLaC*, or stitching the internal fistula opening. Flap formation began with an incision in the perianal area and one of the lateral sides so that the width and height of the flap was 1/3 of the rectal circumference scalpel, scissors and bipolar coagulation with visualization and preservation of the internal anal sphincter. The distal part of the flap was formed by a perianal incision. To assess the blood supply to the flap, depending on its width, repeated administration of ICG at a dose of 0.25 mg/kg with ICG-angiography was performed, followed by video recording for chronometry under conditions of simulated lateral circulatory arrest created by applying a Satinsky clamp on the contra lateral isolated side of the flap. Lateral circulatory arrest was performed as follows: in 3 patients of group 1, as well as in patients of groups 2 and 3, the flap size was 1/3 of the rectal circumference, and in the remaining 3 patients the flap size of 1/4 of the rectal circumference (Fig. 5–8).

After repeated ICG angiography, in all the patients the contra lateral margin of the flap was formed with further fixation of the rectal advancement flap Vicril 2/0.

Retrospective analysis with chronometry of video recordings studied the rectal vascular network and the rectal advancement flap were evaluated, the intervals between intravenous administration of ICG, the beginning of the arterial phase characterizing the intensity of arterial blood flow, and then the venous phase, which is accompanied by maximal fluorescence, that is, the time to achieve complete perfusion of the rectal wall, which characterizes venous outflow, were calculated. There were no intraoperative

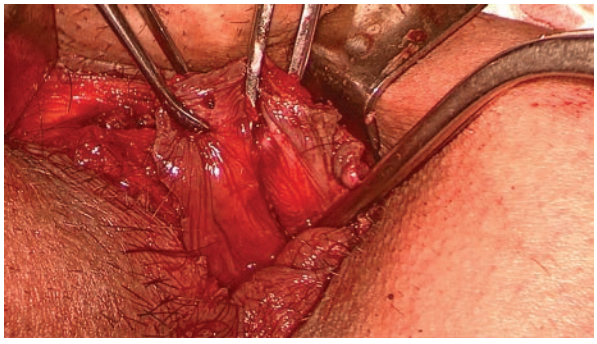

Figure 5. *Lateral circulatory arrest at the advancement flap*

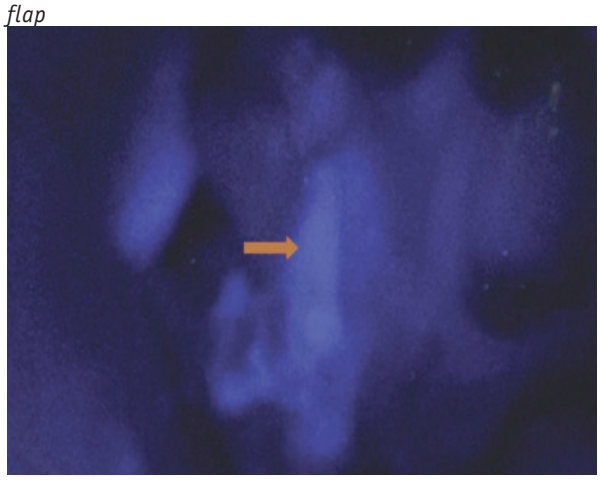

Figure 6. ICG of the rectal advancement flap with the central vessel at lateral circulatory arrest (arterial phase)

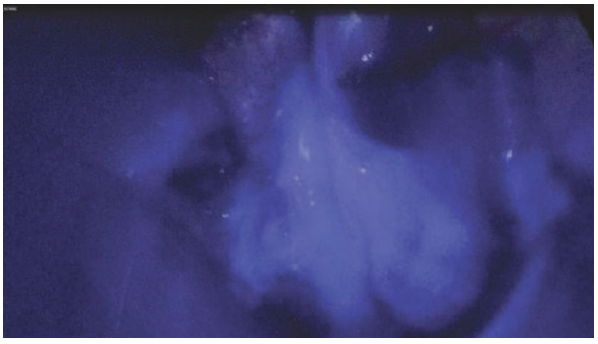

Figure 7. *Phase of maximal fluorescence of the rectal advancement flapat lateral circulatory arrest*

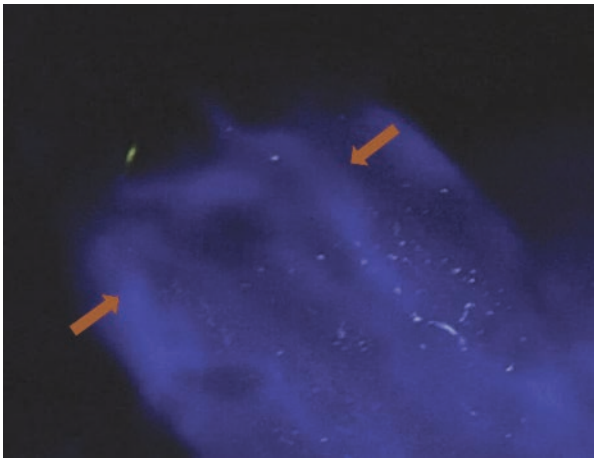

Figure 8. *ICG of the rectal advancement flap with 2 peripheral vessels*

Table 1. *Chronometry of blood supply of intact rectum and rectal advancement flap according to ICG-angiography*

Phase	Chronometry index of the intact rectum			Chronometry index of a rectal advancement flap	
	Group 1 (*n* = 6)	Group 2 (*n* = 2)	Group 3 (*n* = 1)	Rectal advancement flap measuring 1/3 of the rectal circumference under conditions of lateral circulatory arrest (*n* = 6)	Rectal advancement flap measuring 1/4 of the rectal circumference under conditions of lateral circulatory arrest (*n* = 3)
Arterial phase, sec.	31–41 (34.3)	32–34 (33)	35	33–36 (34.3)	32–45 (37.6)
The phase of maximal fluorescence (arterial phase + the beginning of the venous phase), sec.	49–68 (59.3)	54–57 (55.5)*	57*	59–68 (61.5)**	75–80 (77.6)**

*Note: * Statistically significant differences in the indicators of group 1 compared with similar parameters in groups 2 and 3 during ICG angiography of the intact rectum; ** Statistically significant differences in the indicators during the rectal advancement flap formation measuring 1/4 of the rectal circumference compared with similar parameters in the comparison group*

complications. To analyze the immediate and long-term results, patients were examined daily during their stay in hospital, then every week for the next 3 weeks.

STATISTICAL METHODS

Statistical processing of the obtained data was performed on a personal computer in the Statistica 10.0 software package (Statsoft, USA). The Kruskal-Wallis H-test was used to compare the indicators. The differences were recognized as statistically significant at $p < 0.05$.

RESULTS

Distal branches of the rectal arteries were detected in all patients. As already noted in the section 'Patients and Methods', depending on the number of identified arteries, all patients were divided into 3 study groups. Group 1 included patients with 3 distal branches of the rectal arteries, and groups 2 and 3 included patients with 4 and 5 branches, respectively. Taking into account the number of arteries, a rectal advancement flap was formed with a width and height of 1/3 of the rectal circumference in such a way that in patients of group 1 the vessel was in the center of the flap, and in patients of groups 2 and 3 — two adjacent vessels along the flap periphery.

Subsequently, in order to assess blood supply in conditions of simulated lateral circulatory arrest, patients were divided into 2 groups depending on the flap width.

The next step, for a high-level assessment, we studied chronometry of blood supply from video recordings, with an accurate calculation of the time of onset of all phases of both the intact rectum and the rectal advancement flaps of various widths.

The results of chronometry are presented in Table 1.

Due to the detailed chronometry of the video recordings, the mean time of the onset of the arterial phase and the phase of maximal fluorescence of the intact intestine and the rectal advancement flap under simulated lateral circulatory arrest was determined. The time of the onset of the arterial phase, characterizing the intensity of arterial blood supply, was comparable in all groups, regardless of the characteristics of the rectal vascular network.

There was also no significant difference in arterial blood supply and flaps of different widths. However, the following changes in venous outflow were detected: with a rectal advancement

flap width of 1/3 of the rectal circumference, a slight elongation of venous outflow was revealed, expressed in an elongation of the mean time of onset of the maximal fluorescence phase to 61.5 seconds, compared with the intact intestine (58.2 sec.), while with a flap width of 1/4 rectal circumference, there was a significant ($p < 0.05$) prolongation of the mean time of onset of the maximal fluorescence phase to 77.6 sec., that is, 1.26 times compared with that in patients with a flap width of 1/3 of the rectal circumference.

No intra- and postoperative complications developed in all patients, and satisfactory grafting of the flap was noted.

DISCUSSION

Despite the significant number of surgical techniques and their modifications aimed at the surgical treatment of anal fistulas, to date, there is no evidence of the undeniable advantages of any of them and, consequently, a 'universal' approach to the treatment of patients of this profile, and the risks of disease recurrence and postoperative complications remain at a high rate. Thus, according to various studies and meta-analyses, the total recurrence rate of rectal fistulas is at least 20% [4,7,17–20].

In this regard, the problem of treating rectal fistulas has been and still remains unresolved for surgical coloproctology. The issue of choosing the surgery for complex fistulas that involve more than 1/3–1/2 of the external sphincter or are located extrasphincteric, associated with a high risk of anal sphincter incontinence and recurrence, is still controversial.

The 'basic' method, widely used and recommended is fistulectomy with rectal advancement flap, providing efficiency of up to 87%.However, the rate of healing of the fistula with scarring of the anal canal is about 58.3%, the risk of recurrence — up to 7.5%, and the rate of anal incontinence in the range of 7.0–20.4% [4,16,17,19]. These procedures can be attributed to plastic ones, the advantages of which include high efficiency, low risk of sphincter lesion, minimal risk of infection and minimal healing time of postoperative wounds and, accordingly, short periods of rehabilitation after surgery [21].

When performing such procedures, it is necessary to adhere to the canons of safe reconstructive plastic surgery, namely, ensuring adequate blood supply to the rectal flap, absence of tissue tension, optimal ratio of flap width and height, absence of 'dead' spaces and proper postoperative management. It should be emphasized that one of the main reasons for the unfavorable results of surgical treatment is precisely the insufficiency of blood supply to the rectal advancement flap, and therefore, an intraoperative assessment of the blood supply to the formed flap is extremely important.

In this aspect, the method of fluorescent ICG navigation is diagnostically valuable, which allows real-time assessment of the vascular network and timely 'individualize' operational approach. Colorectal surgery, in particular, has turned out to be one of the main areas for the clinical application of ICG-angiography, as it allows quantifying the level of intestinal blood supply, evaluating individual features of the anatomy of the vascular bed and, as a result, ensuring high efficiency and safety of the performed surgery [22].

In our study, using ICG-angiography followed by chronometry, we studied the parameters of the vascular network of the intact rectum and the formed rectal advancement flaps during lateral circulatory arrest. This made it possible to simulate conditions for an objective assessment of the effect of the width of the cut flap on the key chronometric parameters of blood supply — the mean time of the onset of the arterial and venous phases.

As already noted in the section 'Patients and Methods', in each group of patients included in the study, the site and course of the rectal arteries differed: group 1 consisted of patients with 3 large distal branches of the rectal arteries, and groups 2 and 3 — patients with 4 and 5 branches, respectively. Taking into account the number and

sites of the distal branches of the rectal arteries, we determined the margins of flap in such a way that patients with 3 distal branches of the rectal arteries had one vessel in the center of the flap, and patients with 4 and 5 branches had two nearby vessels in the tissues of the flap being formed along the periphery.

As a result, it was found that in the intact rectum, the mean time of the onset of the arterial phase and the phase of maximal fluorescence in all the studied groups was comparable.

Subsequently, during the formation of a rectal advancement flap and the chronometry of video recordings under conditions of lateral circulatory arrest, the following data were obtained: the time of onset of the arterial phase of the intact rectum and the flap of different widths was comparable, while with the width of a rectal advancement flap of 1/3 of the rectal circumference, a slight elongation of venous outflow was revealed, expressed in an elongation of the mean time of onset of the maximal fluorescence phase up to 61.5 seconds, and with a flap width of 1/4 of rectal circumference — in a significant ($p < 0.05$) prolongation of the mean time of onset of the maximal fluorescence phase to 77.6 seconds, that is, 1.26 times compared to that in patients with a flap width of 1/3 of the rectal circumference, which can be explained by a decrease in collateral vessels involved in venous outflow, which, in turn, may be an unfavorable factor for the engraftment of the flap.

Summarizing the results obtained, we conclude that ICG-angiography is an extremely promising method in the anal fistulas surgery, as it allows to visualize the arterial vessels of the rectum intraoperatively, which contributes to the selection of the rectum area margins for the rectal advancement flap formation followed by closure of the internal fistula with adequate blood supply in order to prevent complications in the postoperative period, associated with insufficient blood supply.

CONCLUSIONS

1. ICG-angiography can be recommended for use to assess the vascular network of the rectum and to select margins for the rectal advancement flap with adequate blood supply in the treatment of complex anal fistulas.
2. A detailed analysis of the chronometry of the blood supply to a flap of 1/3 of the rectal circumference in conditions of lateral circulatory arrest revealed the absence of a significant difference in the time of onset of the arterial phase, regardless of the width of the flap compared with the intact rectum. However, a significant elongation of the venous phase with a flap width of 1/4 of the rectal circumference, indicating a deterioration in blood supply due to the intersection of venous collaterals.
3. In connection with the data obtained, it is advisable to isolate a rectal advancement flap of 1/3 of the rectal circumference with a central location of the vessel in patients with 3 distal branches of the rectal arteries, and in patients with 4 and 5 distal branches of the rectal arteries with the marginal location of 2 nearby vessels in the flap, which is accompanied by satisfactory blood supply to the flap.

AUTHORS CONTRIBUTION

Concept and design of the study: *Aleksandr G. Khitaryan, Suleiman A. Adizov*

Collection and processing of the material: *Vasiliy N. Kislyakov, Aleksey A. Orekhov, Kseniya S. Oplimakh, Anastasiya A. Golovina*

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