Effects of Aesthetic Abdominoplasty on Abdominal Wall Perfusion: A quantitative Evaluation

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ABSTRACT:

Abdominoplasty procedures involve a high risk of early complications. These include haematomas, seromas, necrosis, and wound healing problems. Their rationale is evident from the vascular anatomy of the abdominal wall, as traditional abdominoplasty include a division of the main perforating vessels. So far, no studies exist to quantitatively assess the consequences of abdominoplasty on the perfusion of the random pattern abdominal flap. To address this issue and quantify the influence of classical abdominoplasty on the perfusion of the abdominal skin, we performed a prospective clinical trial including fifteen low risk patients undergoing abdominoplasty for aesthetic purposes. Perfusion of the abdominal flap was measured intraoperatively using the technique of dynamic laser-fluorescence-videoangiography. In the region between the umbilicus and the transverse scar (zone 1) the increment of fluorescence (the slope of the intensity curve during inflow of the ICG) was recorded and compared with the intensity curve of normal tissue, which was not involved in surgery (thoracic wall). The results of the intraoperative ICG perfusography showed a significant impairment of the vascular supply of zone 1 in all patients. The mean perfusion index in this region was 17.2% (range 5-32) of the perfusion of the surrounding skin, which was not involved in surgery (Fig. 2). The complication rate was 33% (5 patients) and included 2 cases of haematoma and 3 cases of scar dehiscence with skin and/or fat necrosis. These data indicate that conventional abdominoplasty including extended undermining and division of the superficial and the deep arterial system causes a profound devascularization of the abdominal flap. This might explain the high incidence of complications following this procedure.

Key words: *Abdominoplasty, complications, skin perfusion, fluorescence, laser*.

INTRODUCTION:

Functional abdominal lipectomy was first described by Kelly in 1899[1], and was popularized for cosmetic purposes in 1967 by Pitanguy.[2] He introduced the low transverse incision, which could be concealed in the so-called bikini line and enabled the surgeon to remove all previous lower abdominal scars. Since then, an increasing number of patients seeking truncal rejuvenation have made abdominoplasty a very popular procedure. In 1998, there were 46.597 abdominoplasties performed in the United States.[3] This represents an increase of 177% from the 16.810 procedures reported in 1992.[3]

However, even though the Pitanguy procedure is associated with inconspicuous scars and a high rate of patient satisfaction, the complication rate associated with this kind of surgery is considerable. In the most recent survey of 199 consecutive abdominoplasties, an incidence of minor complications of 32% and an overall revision rate of 43% was reported.[4] In smokers without additional risk factors a complication rate as high as 52% was reported. The complications were related primarily to wound healing, and included haematomas, seromas, skin slough, infection and wound dehiscence. They almost always involved the abdominal skin below the umbilicus. Similar complication rates following abdominoplasty have been found by Floros and Davis[5] and by Uchelen et al.[6] (34.6% respectively 29.2%).

Interestingly, a common finding of most surveys is the lack of correlation between the incidence of complications and the experience of the surgeon.[5,6,7] Thus, even experienced surgeons do not seem to have fewer complications than junior staff.[5] In a large survey of 10.490 abdominoplasties, the authors concluded that those surgeons doing the largest number of abdominoplasties were plagued by the same type of complications as those doing only a moderate number of these procedures.[7] This indicates that ischemia of the abdominal flap and subsequent wound healing problems are inherent to the operative procedure itself and not associated with surgical failure. A thorough study of the abdominal-wall anatomy confirms this assumption: Huger et al. described 3 vascular territories of the abdominal wall.[8] Zone 1 ranges from the xiphoid to the pubis and between the lateral borders of the rectus muscles. This zone is supplied primarily from an arcade formed between the superior and inferior epigastric arteries. Zone 2 is the area defined superiorly by a line from the anterosuperior iliac spine and inferiorly by the groin and the pubic creases. This area receives its blood supply from the superficial epigastric, superficial circumflex iliacs and external pudendal arteries (superficial system), as well as from the inferior epigastric vessels (deep system). Zone 3 comprises the lateral abdomen and flanks and is supplied by segmental lumbar, subcostal and intercostals branches (fig. 1).

Formal abdominoplasty with a low transverse incision and wide undermining to the costal margin sacrifices almost the entire blood supply of zone 1 and zone 2. As the skin of zone 2 is normally resected, zone 1 is left with additional vascular compromise caused by tension on the suture line and thinning of the abdominal flap.

Thus, based on the vascular zones of the abdomen, the profound effects of abdominoplasty on the blood supply of the abdominal wall seem evident. Nevertheless, so far, scientific evidence for the quantitative effects of abdominoplasty on the vascularity of the abdominal skin flap is missing.

Therefore, the purpose of this prospective study was to delineate and quantitatively assess the ischemic areas of the abdominal flap following conventional abdominoplasty. In particular, we wanted to quantify the perfusion of the abdominal skin below umbilicus (in the following called zone 1) to explain the high incidence of wound healing problems in this area.

MATERIALS AND METHODS:

Patients and Operative Technique:

Fifteen consecutive patients undergoing aesthetic abdominoplasty were included in this prospective study. The indications included correction of abdominal wall contour deformity due to muculofascial and skin laxity. Morbidly obese and overweight patients were excluded from the study as were patients with hypertension or diabetes.

The abdominoplasty procedure was performed by a faculty member or by a resident under supervision, using general anaesthesia and muscle relaxation. The operative procedure was done according to Pitanguy or using a standard Regnault W-technique. The abdominal flap was elevated to the xiphoid process centrally and the costal margins laterally and excess skin and subcutaneous tissue was excised. The umbilicus was circumcised and reinserted in a triangular incision on the abdominal flap. In case of true diastasis of the rectus muscles a midline suture plication of the fascia was performed, beginning at the xiphoid process and continuing down to the pubis. Layered closure of the abdominal wound was performed over two suction drains.

No perioperative antibiotic treatment was used. The Medical Ethics Committee of our hospital approved the study.

Evaluation of abdominal flap perfusion:

Abdominal flap perfusion was measured using the technique of dynamic laser-fluorescence-videoangiography (IC-VIEW, PULSION Medical Systems AG, Munich, Germany). After suturing of the abdominal flap had been finished, a single dose of 0,5mg/kg indocyanine green (ICG-PULSION, PULSION Medical Systems AG, Munich, Germany) was injected intravenously, using a peripheral venous catheter. ICG absorbs light in the near-infrared spectral range with a maximum at 805 nm and emits fluorescence with a maximum at 835 nm. Under illumination with a laser (energy P_i=0.16 W, wavelength ?=780 nm) the resulting fluorescence was recorded with a digital video camera using an infrared filter. A special software (IC-CALC, PULSION Medical Systems AG, Munich, Germany) was used for quantitative analysis of the recorded video sequences, where the fluorescence intensity served as a function of tissue perfusion. In the region between the umbilicus and the transverse scar (zone 1) the increment of fluorescence (the slope of the intensity curve during inflow of the ICG) was recorded and compared with the intensity curve of normal tissue, which was not involved in surgery (thoracic wall). The slope of the intensity curve of this region was set to 100%. This allowed a percental comparison of zone 1 with normally, well perfused tissue. The results were presented graphically as the percentage of pixel intensity increment in zone 1 compared to the reference region.

RESULTS:

Patient demographics are shown in table 1. The patients included 14 females and 1 male with a mean age of 39 years (21-60). All patients had a negative past medical history and a body mass index < 30 kg/m^2. Five patients were smokers at the time of surgery. None of the patients underwent co-procedures associated with the abdominoplasty. Seven patients had previous abdominal scars. These included 4 suprapubic scars caused by caesarean section, 3 appendectomy scars, and 3 median vertical scars following laparotomy. The mean time of the hospital stay was 6 days (3-12).

Only minor complications were recorded and the incidence was 33% (5 patients). These included 2 cases of hematoma and 3 cases of scar dehiscence with skin and/or fat necrosis. In all cases, operative intervention was necessary. Only the 3 cases with skin slough and healing problems were regarded associated with ischemia of the abdominal flap. These occurred all in the vascular territory of zone 1. All of the patients with complication were non smokers.

The results of the intraoperative ICG videoography showed a significant impairment of the vascular supply of zone 1 in all patients. (fig. 2). The mean perfusion index of zone 1 was 17.2% (range 5-32) when compared with the surrounding skin, which was not involved in surgery (fig. 2).

A mean of 16.9 ml (12-22) of indocyanine green was injected. No adverse reactions to the injection were noted.

DISCUSSION:

Laser induced fluorescence of indocyanine green (ICG) currently provides the most accurate information on dermal and subdermal microcirculation.[9] It is based on the same objectives as the fluorescence technique using fluorescein, but indocyanine green has overcome the physiological shortcomings of fluorescein. These include a long half-life, diffusion into the interstitium, and an excitation maximum in the ultraviolet spectrum, allowing penetration into the superficial dermis only. The absorption and emission values of ICG lie in the “optical window” of the skin, where the absorption of intrinsic chromophores such as haemoglobin and water is low. Penetrating deeper into the skin, the excitation light induces fluorescence from blood vessels within the deep dermal plexus and subcutaneous fat. In a previous clinical study we were able to show that ICG-videoangiography is a sensitive method for assessing the nutritive blood flow of pedicled skin flaps.[10] A significant correlation between intraoperative dye filling defects and wound healing was found in skin flaps with axial and random pattern blood supply. We concluded that “intraoperative dye filling defects are always a warning signal, indicating critical perfusion in parts of the flap”.

As the abdominal flap in abdominoplasty is considered a random pattern skin flap, there was reason to believe that the ICG-angiography might provide useful information on its vascular supply.

Even though a certain hypoperfusion of zone 1 was assumed, the results of the quantitative assessment were alarming. Thus, we found a mean reduction of skin perfusion in the infraumbilical area of 82.8% (68-95%) when compared with the perfusion of the surrounding skin, which was not involved in surgery (fig. 2). This substantial compromise of the circulation of the abdominal flap probably reflects the division of the dominant vessels including the musculocutaneous perforators from the epigastric artery, the superficial epigastric, superficial circumflex iliacs and external pudendal arteries. The unavoidable tension on the wound closure and an eventual thinning of the abdominal flap might accentuate the ischemia of the skin and cause skin necrosis. Looking at the ICG-perfusography in fig. 3d one can actually recognize the cutaneous vessel network of the superficial circumflex iliacs and external pudendal arteries below the transverse scar, the significant impairment of vascularity of the midline, and the compensatory blood inflow coming from the subcostal and intercostal arterial branches. It seems obvious from this perfusography that the compensatory blood supply from the side and from above is insufficient to supply the infraumbilical skin. As a matter of fact, this particular patient showed secondary healing due to fat necrosis and wound dehiscence of the transverse scar (fig. 3b).

Interestingly, even though a significant perfusion deficit of zone 1 was found in all of the patients in the study (table 1), only three of them developed ischemia related complications with skin slough and wound dehiscence. Apparently, even a substantial perioperative ischemia does not necessarily predispose to wound healing problems during the postoperative course. This confirms previous findings of our group in patients undergoing pedicle flap surgery[10].

A possible explanation may be a potential ischemia protective effect of the sudden interruption of the main blood supply to the abdominal flap. Significant evidence exists to prove the protective effects of ischemic preconditioning on the survival of pedicle and myocutaneous flaps[11,12]. In a recent experimental study, ischemic preconditioning was demonstrated to cause an enhancement of flap survival in random pattern skin flaps, as well[13]. In this study, a sudden period of ischemia followed by reperfusion was shown to significantly increase the survival of a bipedicled skin flap in a rat model[13]. Although the mechanism is not yet completely understood, sudden ischemia was proposed to cause a systemic release of substances, which lead to enhancement of flap survival[12]. The lack of ischemia related complications in patients with critically low perfusion indices indicate a postoperative recovery of the ischemic skin areas; whether this recovery was due to compensatory vasodilation caused by systemically released transmitters during the period of maximal ischemia obviously remains speculative.

The higher complication rate, which has been reported in smokers, could not be confirmed in the actual study. Thus, all of the patients with ischemia related complications were non smokers. Apparently, nicotine associated skin vasoconstriction, which has been reported to cause a considerable decrease in the microcirculatory flow of the skin[4,14], did not play a significant role in our low risk patient population. In patients with obesity, where a threefold complication rate has been reported[15], the adverse effects of smoking might be more significant. This is probably due to the higher metabolic demands of fat cells, which lead to fat necrosis, when the oxygen supply is critically decreased.

Thus even though the complication rate of this study seems rather low, it should be taken into account, that only low risk patients without obesity, hypertension or diabetes were included. Several large scale clinical studies exist, which prove a significantly higher incidence of complication in a non-selected patient population.[4,5,7,14,15].

From the current study, it seems that ischemia of the abdominal flap and subsequent wound healing problems following abdominoplasty are actually inherent to the operative procedure and not associated with surgical failure. Division of the superficial and the deep arterial system caused by the low transverse incision and the extended undermining probably causes a profound devascularization of the abdominal flap, which makes it prone to wound healing problems.

Nevertheless, extended undermining still remains the surgical gold standard in abdominoplasty. In the biggest survey so far, including more than 10.000 abdominoplasties, 9 of 10 surgeons reported that they did a complete undermining to the costal margin.[7] The high complication rates probably serve to document this clinical practice.

However, several reports exist that extended dissection of the abdominal flap is not obligatory and that similar results can be obtained using limited undermining. In 1974, Baroudi proposed a dissection of the abdominal flap, which was limited to a triangular pattern from the xiphoid to the anterior superior iliac spine.[16] He believed that this method of limited dissection preserved some intercostals perforators and thus improved overall flap perfusion. In 1992, Illouz performed a discontinuous undermining technique by dissecting the supraumbilical abdominal flap by liposuction.[17] In addition; he performed minimal undermining of the supraumbilical midline in situations where plication was to be performed. He noted that adequate flap mobility could be achieved while improving flap perfusion by preserving arterial perforators[17]. The utility of these techniques has later been confirmed by other authors [18,19.20] .

Another possibility, which has not been previously reported, is the selective dissection and preservation of one or more perforator vessels from the superior epigastric artery. This may eventually change the blood supply of the abdominal flap from a random pattern into an axial pattern blood supply and thus improve skin perfusion in zone 1. In our experience there are most frequently one or more big perforators present in this region, which can easily be dissected while preserving the mobility of the flap. In a recent experimental study, most of the abdominal skin of the rat was shown to be able to survive on the basis of a single muculocutaneous perforator vessel [21]. This confirms the clinical experience with the deep inferior epigastric perforator flap [22].

We have evaluated only a few cases, and our experience so far does not allow any conclusion to be drawn. Nevertheless, the profound effects of preserving even one arterial perforator seem clearly visible from the ICG-perfusography. Fig 4a shows a 54 year old patient, who was operated with a conventional low transverse abdominoplasty according to Pitanguy. One large musculocutaneous perforator in the right supraumbilical area was dissected and preserved when elevating the abdominal flap (fig. 4c). Fig. 4e demonstrates the result of intraoperative ICG-perfusography with a clear improvement of perfusion in the right part of the infraumbilical region. A reinforced cutaneous vessel network was seen in the right part of the abdominal wall, when compared with the patients where a complete undermining had been performed (fig.3d).

To our knowledge this is the first study in the literature which provides a scientific approach to the effects of abdominoplasty on skin perfusion. Even though the number of patients is too small to provide statistical proofs, the profound effects of an extended undermining are clearly documented. Whereas non-obese patients without co-morbidities may be able to compensate the vascular compromise associated with this operation, patients with obesity, diabetes or hypertension may develop irreversible skin ischemia. Based on the actual findings it is surprising that operative techniques including limited undermining have never found general acceptance among plastic surgeons. We have changed our operative technique following the conclusion of this study. In a full abdominoplasty, the flap is now undermined in an inverted V fashion, preserving the intercostal blood supply and elevating the flap only to the degree necessary to achieve wound closure without tension and repair of the diastasis. Alternatively, muculocutaneous perforators are dissected and preserved.

Even though the most frequent complications associated with abdominoplasty have been described as “minor” and “insignificant”, and can be most frequently managed easily, abdominoplasty is still associated with a significant morbidity. Therefore, future studies are warranted, which evaluate the quantitative effects of limited dissection techniques and of preservation of perforator arteries. The goal should be to provide a sound operative technique, which is based on a thorough knowledge of the vascular anatomy of the abdominal wall.

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LEGEND TO FIGURES AND TABLES:

Figure 1: The vascular zones of the abdominal wall.

Figure 2: Perfusion index of the infraumbilical skin (zone 1, yellow bars) as percentage of the reference region (normal skin; blue bars).

Figure 3a: Twenty-six year old female with musculofascial and skin laxity following 50 kg weight loss.

Figure 3b: Intraoperative situation shortly after suturing of the abdominal flap.

Figure 3c: 3 weeks following abdominoplasty with wound dehiscence and skin and fat necrosis of the infraumbilical area.

Figure 3d: Result of intraoperative ICG-perfusography.

Figure 3e: Increment of fluorescence (pixel intensity) measured as steepness of the curve of light emission (pixel intensity/sec) for the reference region (green) and for the infraumbilical region (red). The light green curve served for calibration of the camera only.

Figure 4a: Fifty-four year old women with abdominal wall contour deformity due to excess skin and fat. Note the adherent appendectomy scar on the lower abdomen.

Figure 4b: Three weeks following abdominoplasty.

Figure 4c: Large muculocutaneous perforator artery in the supraumbilical area.

Figure 4d: Intraoperative situation shortly after suturing of the abdominal flap.

Figure 4e: Result of intraoperative ICG-perfusography.

Table 1: Demographic data, complications and pixel intensity.

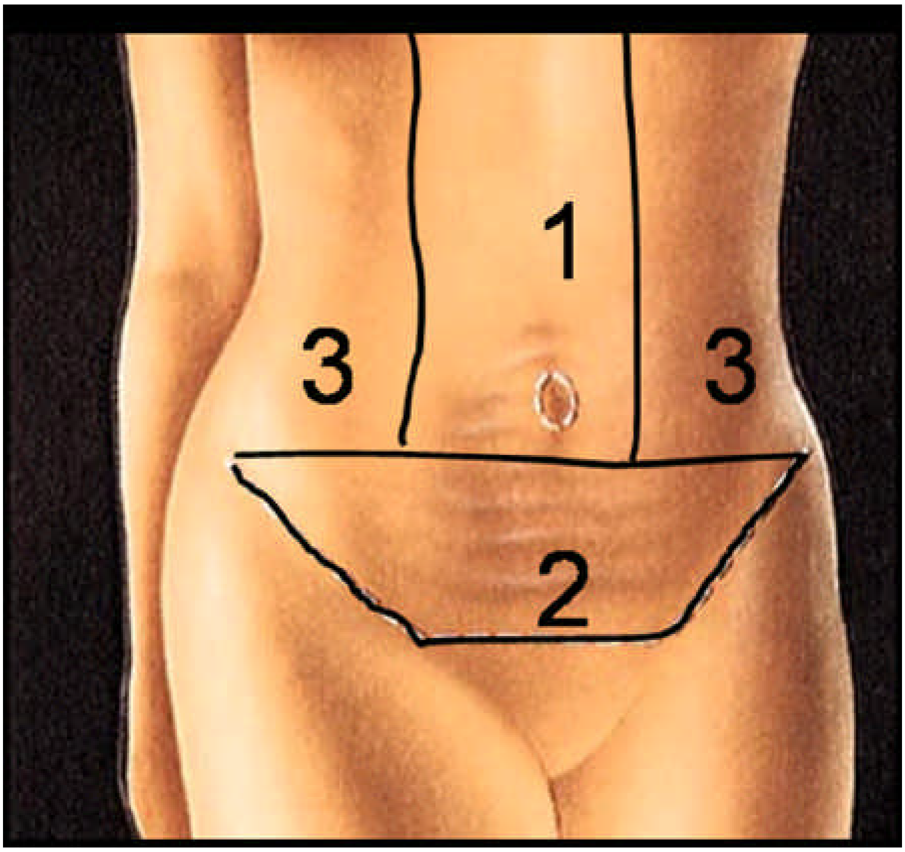

Fig. 1

Patient number	Sex	Age (years)	BMI (kg/m²)	Amount of tissue excised (grams)	Area of tissue excised (cm²)	Nicotine (Cig./d)	complications	Pixel-intensity (%)
1	female	44	20.1	200	444	15	no	16
2	female	47	20.9	248	408	0	hematoma	24
3	female	34	24.5	910	684	15	no	10
4	female	60	26.6	2062	1176	20	no	15
5	female	53	25.8	1444	1008	25	no	25
6	female	45	20.4	256	270	15	no	19
7	female	40	19.0	200	405	0	no	5
8	female	26	22.7	1000	544	0	skin/fat necrosis	5
9	male	21	24.6	614	468	0	skin/fat necrosis	15
10	female	39	23.6	1212	800	0	no	24
11	female	25	29.4	1746	560	0	no	32
12	female	54	22.3	662	378	10	no	7
13	female	34	22.3	550	360	0	hematoma	30
14	female	23	23.5	375	400	0	no	19
15	female	42	26.4	514	432	0	skin/fat necrosis	12

Table 1

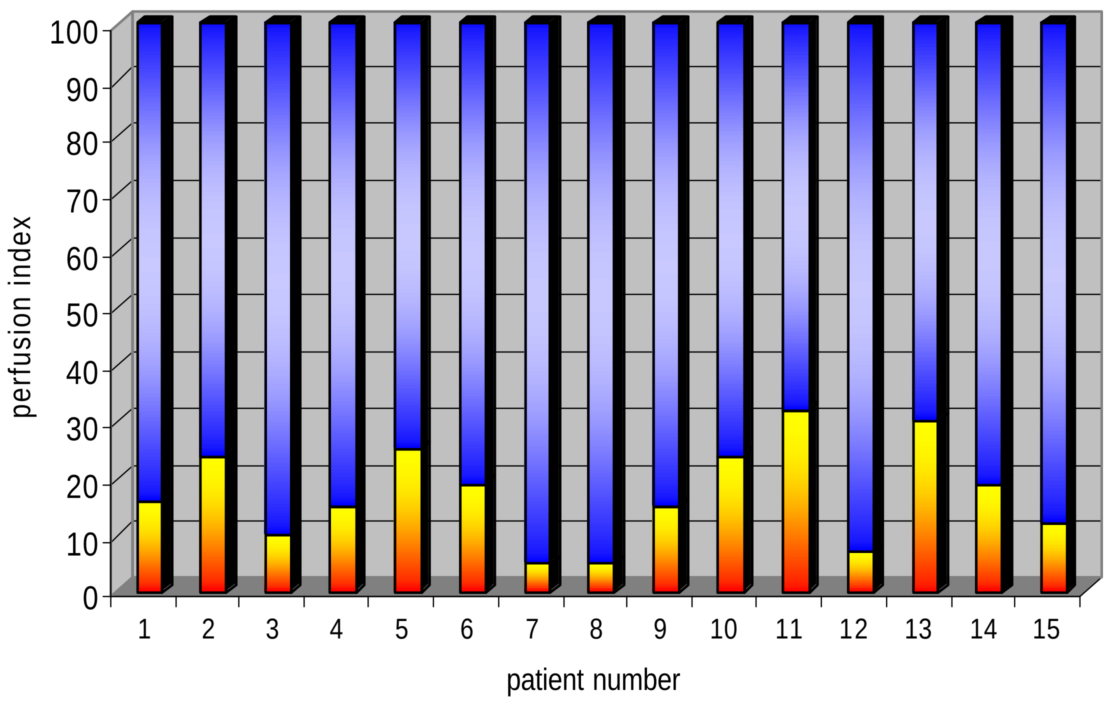

Fig. 2

Fig. 3a-d

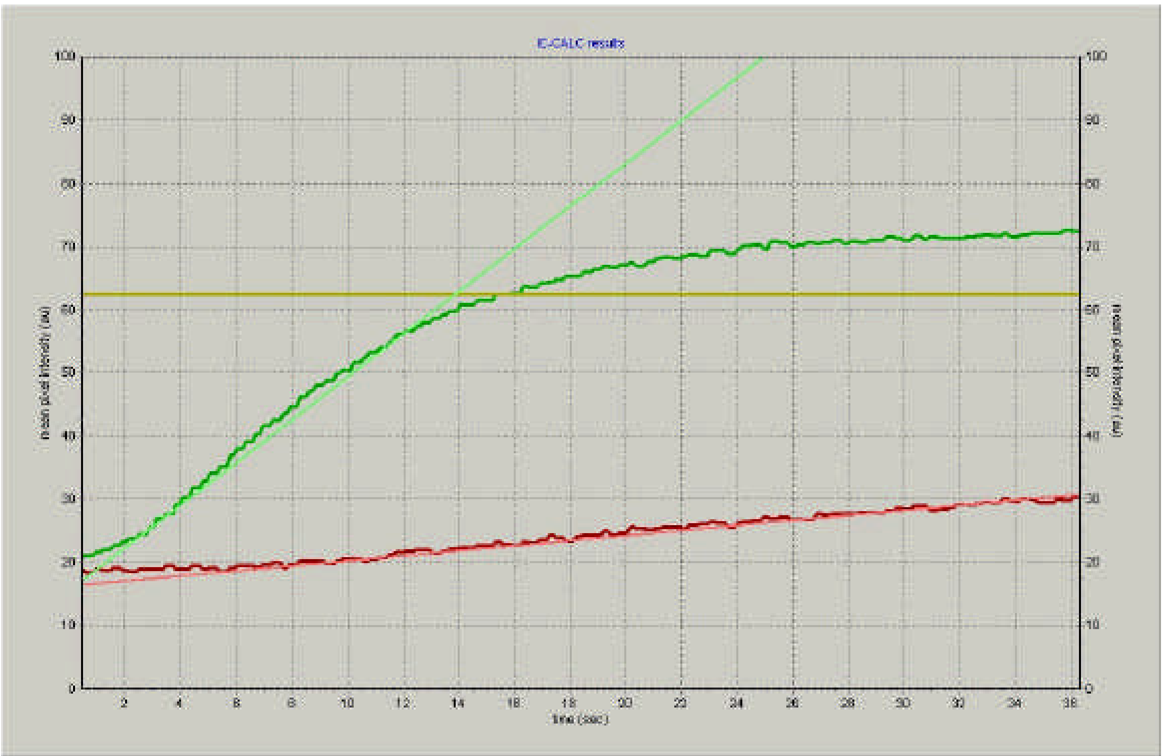

Fig. 3e

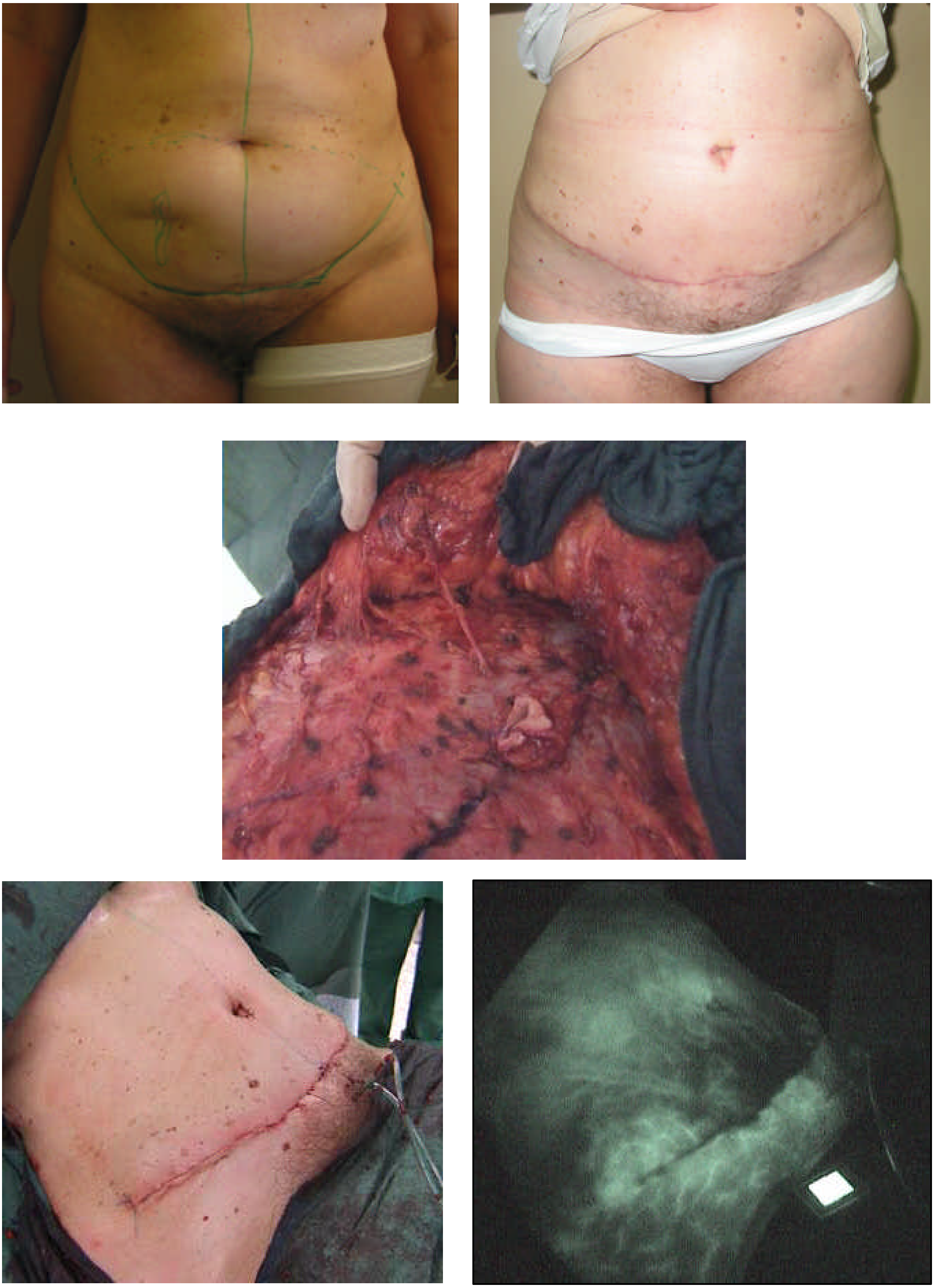

Fig. 4a-e