



# Prospective analysis of flap perfusion by measuring capillary glucose level in flaps

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## Abstract

**Background** Post-operative monitoring of flap is equally important as harvesting of a flap. Early diagnosis of flap failure can salvage the flap by appropriate intervention. The monitoring methods used should be rapid, inexpensive, and accurate. The purpose of this study is to evaluate the usefulness of blood glucose monitoring (BGM) of the flap as our monitoring modality.

**Methods** This study includes 60 flaps which were monitored by measuring their capillary glucose level by pricking the distal end of the flap. Out of the 60 flaps, 18 were free flaps, 23 were pedicled, and 19 were of the random variety. Quantitative data was expressed in frequency, percentage, mean value, and standard deviation for capillary glucose levels of the flap.

**Result** Out of the 60 flaps, 44 survived well, 10 flaps were having minor distal necrosis (< 10% of flap area), major flap necrosis occurred in 3 flaps while 3 flaps failed completely. Failed flaps have shown lower glucose levels. Using the receiver operating characteristic curve (ROC), the cutoff value for BGM was 61 mg/dl, with a sensitivity of 93% and a specificity of 80%.

**Conclusion** Blood glucose monitoring reveals the state of perfusion of the flap in the postoperative period. Flap capillary glucose levels less than 61 mg/dl is suggestive of ischemia of the flap with a sensitivity and a specificity of 93% and 80%, respectively. It has prognostic value as it allows early detection of vascular compromise and also defines the forthcoming line of demarcation in partial necrosis.

Level of Evidence: Type IV, diagnostic study.

**Keywords** Blood glucose monitoring · Hypoperfusion · Demarcation · Ischemia · Flap prognosis

## Introduction

Flap coverage for a tissue defect is one of the frequently performed surgeries by reconstructive surgeons. Viability and success of a flap holds importance for the surgeon as well as the patients. Hence, a reliable assessment method is required for the early detection of flap ischemia, as the window period between onset of circulatory compromise and intervention is limited but crucial for the flap outcome [1, 2]. Clinical observation is still the gold standard of flap assessment, despite its inherent problems [3].

In addition to conventional clinical monitoring, various method of monitoring have been developed and used such as laser Doppler, microdialysis, near-infrared spectroscopy, dynamic CT, and MRI but none of these methods mentioned have become a gold standard [4–7].

Most vascular insufficiency usually occurs within 3 days of flap surgery; therefore, routine monitoring of all flaps is a key for salvage. Capillary glucose monitoring is highly sensitive and specific for vessel occlusion and offers a rapid, inexpensive, and accurate method of flap monitoring [8].

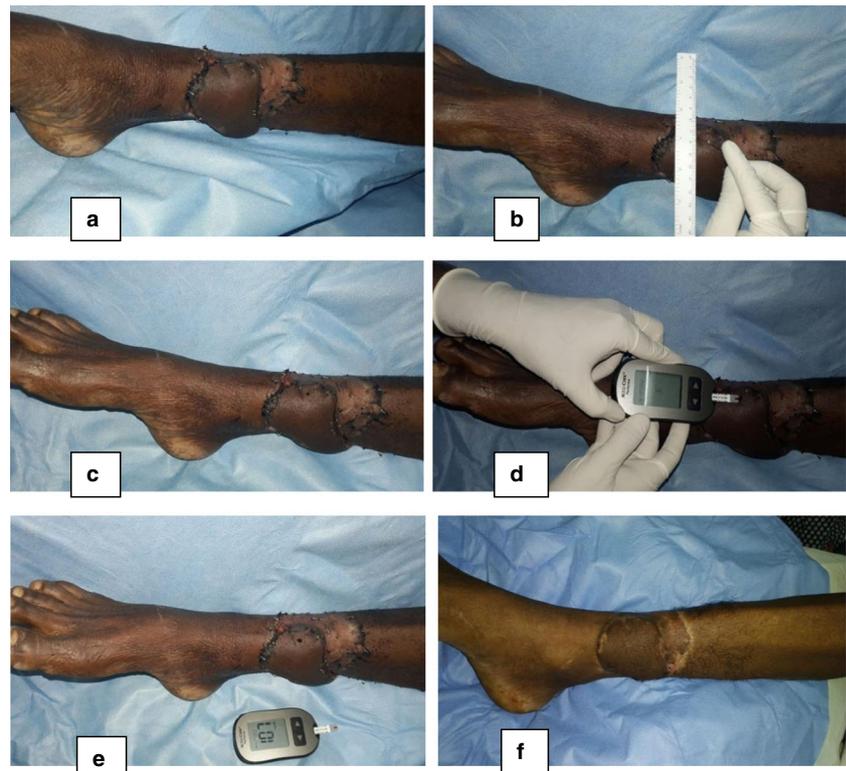
Sakakibara et al. [9] were first to report the use of glucometer as a monitoring tool for flap perfusion in clinical cases and lower blood glucose is indicative of flap hypoperfusion. The purpose of this study is to establish that measurement of flap glucose can be used as a simple and effective screening tool along with clinical examination for early detection of flap hypoperfusion.

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**Fig. 1** Blood glucose monitoring of flap. **a** Soft tissue defect lower third leg, covered by reverse sural artery flap (post-op). **b** Pricking the flap by a 26-G needle. **c** Blood oozing from the flap. **d** Glucometer with strip to collect drop of blood. **e** Glucometer showing flap glucose level. **f** One-month-later picture after flap division and inseting



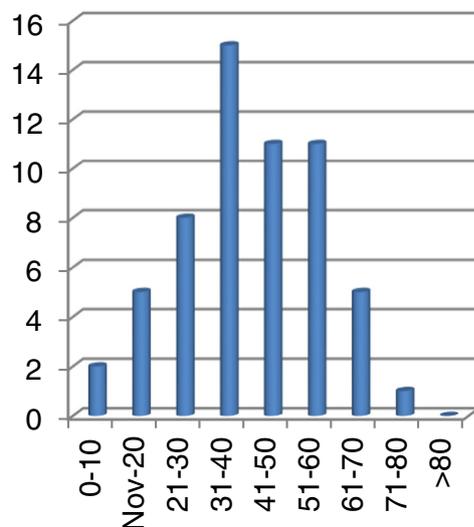
## Material and Methods

This study was conducted in Christian Medical College, Vellore, during March 2013 to September 2013. Flap monitoring was done postoperatively by measuring the flap blood glucose levels. Initially, it was on an hourly basis for the first 6 h, then every 2 h for the next 2 days and then 6-hourly for the remaining 3 days. If a serial blood glucose monitoring (BGM)

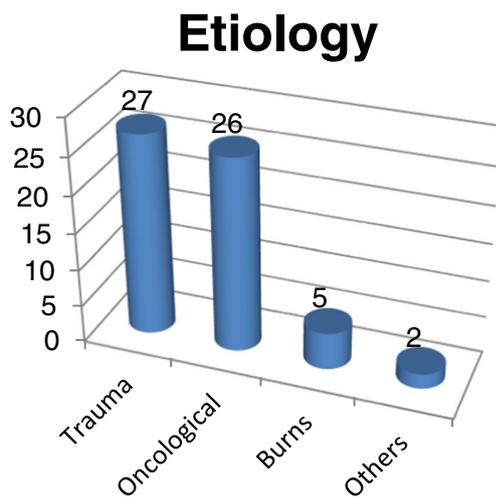
showed a fall in the glucose value, more frequent (half hourly) readings were taken and correlated clinically.

Flap blood was sampled by pricking the flap area which is 1 cm from its distal margin with 26-G needle and measuring blood glucose with available glucometer in the ward (Fig. 1). All patients undergoing pedicled/free flap surgery were included, while patients with buried flaps and patients who were hypotensive and on inotropic drugs or having diabetes mellitus were excluded from the study. Blood glucose monitoring (BGM) of flap by glucometer in these cases could provide false results [10]. Final diagnosis of flap failure was made by senior plastic surgeon according to clinical features described by Mathes [11]. To minimize the bias, the person monitoring the blood glucose did not make the clinical diagnosis of flap failure. Quantitative data were expressed in frequency and percentage. Data were expressed as mean value and standard deviation for capillary glucose levels in flap. Diagnostic accuracy measuring sensitivity and specificity was calculated with 95% confidence interval. In order to decide the best cutoff value, receiver operating characteristic curve (ROC) was plotted with clinically assessed tissue to delineate survival or failure. These findings were tabulated against the monitored glucose value. Flap capillary blood glucose levels were graphically arranged for surviving and failed cases; ROC curve was plotted. The best of all these ROC curves was identified and the best cutoff value of blood glucose for this ROC was selected. The data collected was divided into two groups, i.e., values noted in patients with survived

## Age Distribution in Years



**Fig. 2** Age distribution of patients in years



**Fig. 3** Patient etiology

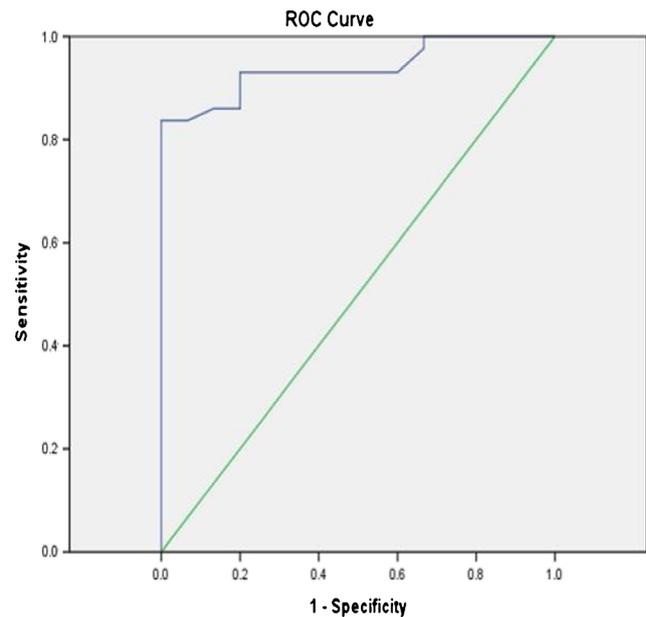
flap and in patients with flap failure. Chi-square test was done to check the relationship between low blood glucose level of flap and ischemia.

## Results

A total of 60 patients were included in this study of all ages (Fig. 2). Among them, 77% were males and 23% were females. There were 18 free flaps, 23 pedicled axial flaps, and 19 random pattern flaps. Trauma and tumor excision were the most common indications for flap coverage (Fig. 3). Out of the 60 flaps, 44 survived well without any complication, while minor distal necrosis (<10% of total area of the flap) occurred in 10 flaps and major flap necrosis occurred in 3 flaps. Three flaps mobilized by free tissue transfer had complete necrosis. Using ROC curves, the coordinates of curve, sensitivity, and specificity were determined (Fig. 4) (Table 1). A flap capillary glucose value of 61 mg/dl was proposed as a cutoff value for which the sensitivity was 93% and the specificity was 80%. A value less than 61 mg/dl was seen to be suggestive of flap ischemia. Keeping the cutoff value as 61 mg/dl, cross-tabulation was made to calculate the positive predictive value (PPV) and the negative predictive value (NPV) (Table 3). Mean glucose values were significantly low in the non-survival group (Table 2). The *p* value obtained by chi-square test was <0.5, which rejects the null hypothesis and indicates a strong relationship between low flap BGM and ischemia (Table 3).

## Discussion

This study done on a variety of flaps (Table 4) showed that the level of blood glucose gets reduced if flap goes



**Fig. 4** Receiver operating characteristic curve (ROC) showing diagnostic performance of blood glucose monitoring (BGM) of flap monitoring

into failure. Analysis of the results obtained shows that interstitial glucose monitoring of flaps is highly sensitive and specific for detecting flap hypoperfusion. In 2010, Sakakibara et al. [9] reported a lower blood glucose level in all five congestive free flaps. Hara et al. [12] described blood capillary glucose measurement in flaps in post-operative period and the use of BGM for flap monitoring. Setala et al. [13] found that the blood glucose level in flaps is reduced in ischemic or congestive conditions by using micro dialysis.

Although microdialysis shows excellent sensitivity and specificity, the instrument is very complicated and expensive. Personnel requires a basic training before using it; a microcatheter needs to be introduced in the flap for monitoring which has to be fixed with the skin and which requires removal later on. Microcatheter can get detached if not fixed properly or it can get clogged due to hematoma which cause interruption in analysis. The analysis of flap blood sample by this method may take up to 15 min [14].

Similar difficulties are faced while using laser Doppler for flap monitoring such as improper or unfavorable attachment of the probe, obstruction of laser beam, and flowmeter mechanical failure which can lead to artifacts, which the surgeon or monitoring personnel should keep in mind.

For flap monitoring by implantable Doppler, a silicon cuff has to be wrapped over the anastomosed vessel and a Doppler probe is attached to it, which is pulled out post-operatively, when the monitoring period is over. The drawback in this method is that the Doppler probe

**Table 1** Coordinates of ROC curve

Value of flap blood sugar (mg/dl)	Sensitivity	Specificity	1-Specificity
55	0.930	0.733	0.267
61	0.930	0.800	0.200
64	0.907	0.800	0.200

wire can be accidentally pulled out requiring flap reelevation for placement again. There is also a theoretically risk of damaging the anastomosed site while pulling out the probe; it is also technically demanding to wrap a silicon cuff around a small caliber vessel and the continuous monitoring sound produced by the Doppler machine may be annoying to the patient.

The study done by Wax [15] over 1142 flaps monitoring by this method shows an 87% sensitivity and a 99% specificity while another study done by Frost et al. [16] shows a sensitivity of 66.67%.

The overall cost of above three mentioned instruments is quite high which can be a financial constraint for a low-volume center. The blood glucometer is a simple, handy, cheap instrument which is easy to use. No special training is required; there is no significant learning curve and a fine prick is all it takes to get the required blood sample with results yielding within 10–15 s.

Furthermore, this method is more quantitative than the traditional ways of flap monitoring and can easily be done by surgeon, registrar, or nursing staff.

In the current study, a cutoff value for the BGM of 61 mg/dl is proposed at which the sensitivity and specificity were 93% and 80%, respectively.

In the present study, the blood glucose level showed a gradual elevation with time. The reason of this gradual elevation may be that in immediate post-operative period due to tissue handling the blood flow to the flap gets decreased, which slowly improves with time.

**Table 2** Testing significance of association of flap blood glucose level and survivability of flap

	Survived	Not Survived
Mean (mg/dl)	109.2	42.5
Median	113	43
Min. value (mg/dl)	46	0
Max value (mg/dl)	182	76

**Table 3** Diagnostic performance of test

Variable	Values
Cutoff value (mg/dl)	61
Sensitivity	93
Specificity	80
Positive predictive value	0.88
Negative predictive value	0.83

We also noticed that the blood glucose value in the failing flaps decreases to low value before any clinical signs set in. During free flap monitoring, if blood glucose values drop in distal region, additional BGM was carried out proximally at several points. If low blood glucose was noticed in all the points, we suspected anastomotic site issues; accordingly, clinical review was done of the failing flap by senior plastic surgeon to decide about urgent reexploration. In the cases where only distal locations on the flap showed low blood glucose levels while other points indicated normal glucose levels, the flap was not reexplored as in those cases, anastomotic site failure was not the reason for hypoperfusion. It was also noticed that once the flap perfusion was reestablished by intervention, the glucose level regained normal levels, while in the case of pedicled or random pattern flap, low glucose level was suggestive of compression, underlying hematoma, or kinking of pedicle. If any of the abovementioned reason

**Table 4** Flaps characteristics

Types of flaps	Number
Free anterolateral thigh (ALT)	5
Free fibula with skin island	5
Free radial forearm	3
Free latissimus dorsi muscle (LDM)	2
Free medial sural artery perforator	3
Pedicle ALT	3
Pedicle tensor fascia lata	2
Pedicle paramedian forehead	1
Pedicle groin	2
Pedicle LDM	2
Propellar posterior tibial artery perforator	3
Reverse sural artery	8
Distally based posterior tibial artery perforator	2
Random abdominal flap	2
Other random flap	17

was found as a cause of hypoperfusion efforts such as decompression, removal of suture and drainage of collection or readjustment of flap pedicle position were made to salvage it or to reduce the extent of distal necrosis. If no reason was found, the flap was left undisturbed until the line of demarcation develops between viable and non-viable flaps.

Most of our flaps in this study were done in high-intensity trauma patients with extensive soft tissue injury which may be the reason we see a relatively high failure rate in this series of flaps. These flaps were performed on day 1 of injury on an emergency basis.

The disadvantage of BGM remains that it is not useful in the cases of buried flaps or if the amount of blood sample withdrawn is not sufficient for testing. In our study, we did not encounter such, as we got adequate blood in every case. This method is safe because the depth of the puncture is up to the dermal layer which practically does not affect the vascularity of the flap. BGM holds significance for monitoring intraoral flaps, which are otherwise difficult to monitor clinically.

BGM also delineates the *line of demarcation* distal to which flap is hypoperfused. Whenever low blood glucose levels were noticed in the flap, BGM was done proximal to it in a sequential manner until normal blood glucose levels were obtained, pointing to a possible line of demarcation.

BGM also has a *prognostic* value in that a rapid rate of fall in the levels of blood glucose is highly sensitive for vessel occlusion such as vascular thrombosis.

There are not many studies available in which the efficacy of flap monitoring by glucose measurement is evaluated. The method of flap blood glucose monitoring is objective, feasible, and inexpensive which can be done by any health care professional and does not require any specialized facilities or training.

## Conclusion

Blood glucose monitoring of flap is an indicator of the perfusion of flaps in the postoperative period. Flap capillary glucose levels less than 61 mg/dl are suggestive of ischemia with sensitivity and specificity of 93% and 80%, respectively. It allows early detection of vascular compromise, has prognostic value, and also defines the line of demarcation in partial necrosis.

## Compliance with ethical standards

**Funding** This study is funded by Institutional Review Board, Christian Medical College, Vellore Tamil Nadu (India).

**Conflict of interest** Mukesh Kumar Sharma, Geley Ete, Gaurav Chaturvedi, Elvino Barreto, and Kingsly Paul Meetper Doss declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

**Patients consent** Patients provided written consent for the use of their images.

## References

1. Biemer E (1981) Salvage operations for complication following replantation and free tissue transfer. *Int Surg* 66(1):37–38
2. Genden EM, Rinaldo A, Suárez C, Wei WI, Bradley PJ, Ferlito A (2004) Complications of free flap transfers for head and neck reconstruction following cancer resection. *Oral Oncol* 40(10):979–984
3. Neligan PC (1993) Monitoring techniques for the detection of flow failure in the postoperative period. *Microsurgery* 14(3):162–164
4. Rodjmark J et al (2000) Comparison of flap ischaemia induced by arterial or venous occlusion in pigs with aid of microdialysis. *Eur J Plast Surg* 23(5):278–282
5. Hutchinson DT (1993) Color duplex imaging. Applications to upper-extremity and microvascular surgery. *Hand Clin* 9(1):47–57
6. Thorniley MS, Sinclair JS, Barnett NJ, Shurey CB, Green CJ (1998) The use of near-infrared spectroscopy for assessing flap viability during reconstructive surgery. *Br J Plast Surg* 51(3):218–226
7. Yuen JC, Feng Z (2000) Monitoring free flaps using the laser Doppler flowmeter: five-year experience. *Plast Reconstr Surg* 105(1):55–61
8. Sitzman TJ, Hanson SE, King TW, Gutowski KA (2010) Detection of flap venous and arterial occlusion using interstitial glucose monitoring in a rodent model. *Plast Reconstr Surg* 126(1):71–79
9. Sakakibara S, Hashikawa K, Omori M, Terashi H, Tahara S (2010) A simplest method of flap monitoring. *J Reconstr Microsurg* 26(07):433–434
10. Tonyushkina K, Nichols JH (2009) Glucose meters: a review of technical challenges to obtaining accurate results. *J Diabetes Sci Technol Online* 3(4):971–980
11. Mathes. *Plastic surgery, general principal*. Vol. 1. Saunders; 496–497 p
12. Hara H, Mihara M, Iida T, Narushima M, Todokoro T, Yamamoto T, Koshima I (2012) Blood glucose measurement for flap monitoring to salvage flaps from venous thrombosis. *J Plast Reconstr Aesthet Surg* 65(5):616–619
13. Setälä LP, Korvenoja EM-L, Härmä MA, Alhava EM, Uusaro AV, Tenhunen JJ (2004) Glucose, lactate, and pyruvate response in an experimental model of microvascular flap ischemia and reperfusion: a microdialysis study. *Microsurgery* 24(3):223–231
14. Jyranki J et al (2006) Microdialysis in clinical practice: monitoring intraoral free flaps. *Ann Plastic Surg* 56(4):387–393

15. Wax MK (2014) The role of the implantable Doppler probe in free flap surgery: Doppler use in monitoring of free flaps. *Laryngoscope* 124(S1):S1–S12
16. Frost et al (2015) Direct comparison of postoperative monitoring of free flaps with microdialysis, implantable cook-Swartz Doppler probe, and clinical monitoring in 20 consecutive patients: postoperative monitoring in 20 consecutive patients. *Microsurgery* 35(4): 262–271