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Original Research Article

A Study of Flap Capillary Blood Glucose Monitoring as a Predictor of Flap Survival

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Conflict of interest: Nil

Abstract

Background: Monitoring glucose levels in flap tissues can be a valuable indicator of flap viability and early detection of flap failure. This study aimed to analyze the utility of intra-flap glucose monitoring in predicting flap outcomes.

Materials & Methods: It was a single centre, single arm, non-comparative longitudinal observational study done from May 2019 to October 2020. Thirty (31) patients, operated for reconstruction with various flap incorporating skin in the department of plastic and reconstructive surgery after taking informed written consent. Flap blood glucose levels have been measured at scheduled times by glucometer. At the same time blood glucose levels has been measured from adjacent normal skin (control site). In addition to blood glucose assessment simultaneous clinically findings have been noted and correlated. In the event of any indication of impending/frank ischemic changes appropriate measures have been taken by the surgeon in-charge. Capillary blood sample has been taken by pin prick method at the distal most part of flap. At the same time patient blood glucose level has been measured from normal skin adjacent to flap. Samples were taken in immediate post-operative period then after 1hr, 12 hr, 24 hr, 48 hr and 72 hr after operation.

Results: Out of thirty-five patients, thirty were male and five were female. Among four free flaps, three were antero-lateral (ALT) fascio-cutaneous flap and one was free latissimus dorsi (LD) musculocutaneous flap. We have measured flap blood glucose and body blood glucose from control site simultaneously and then calculated flap blood glucose as a percentage of body blood glucose. Out of 35 flaps, 21 flaps have done well and no sign of ischemia was found in these flaps. Blood Glucose levels of these flaps were taken at regular intervals as per study schedule. Total 63 values have been recorded from clinically ischemic flaps. Blood glucose values of ischemic flaps were significantly low with a mean value of 35.81% of body glucose. At the intervals of immediate, 1hour, 6-hour, 24-hour, 48-hour, 72 hour, 5 days the mean values of glucose are lower in necrosed flap than survived flaps. It was found to be statistically significant ($p<0.05$).

Conclusion: Intra-flap glucose monitoring is a reliable method for predicting flap viability. Higher glucose levels are associated with flap survival, providing a potential tool for early intervention in cases of impending flap failure.

Keywords: Flap perfusion, blood glucose measurement (BGM), flap viability, flap failure, trauma reconstruction, flap surgery outcomes.

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Introduction

Flaps are one of the most important tools of reconstructive surgery. It holds the highest place in reconstruction ladder. A careful, regular flap monitoring is required to predict the viability of flap. Early detection and exploration of compromised perfusion provide options to correct problems and to save a flap. Ideal flap monitoring system may differ depending on the type of flap. None of the presently available monitoring systems fulfil the requirement [1, 2, 3]. Direct clinical observation is still the gold standard monitoring system. Assessment of flap skin colour and its comparison with adjacent normal skin is a valuable indicator of flap viability. Capillary refill time is an adjunct to skin colour assessment in flap monitoring. A pink colour of skin and capillary refill indicates arterial insufficiency, whereas a dusky colour with brisk capillary refill can represent venous congestion [4].

The most reliable clinical indicator of flap status is the colour of the blood that oozes from the flap on pin pricking with a needle. Bright pink oozing represents a healthy flap, whereas dark purplish oozing reflects compromised perfusion of the flap [5]. Among other monitoring methods fluorescence has long been used to assess the skin perfusion. After an intravenous bolus of fluorescence, the tissue is examined with an ultraviolet lamp. Adequately perfused tissue fluorescence, whereas inadequately perfused tissue is not seen with the ultraviolet lamp. It usually underestimates the amount of tissue that will ultimately survive. Serial use of this method is also cumbersome and expensive also [6].

Another commonly used method is surface temperature monitoring to assess flap viability. Subjective variability is major drawback of surface temperature monitoring. Differential thermometry is more reliable method but it also varies with environmental factors [1]. Conventional doppler ultrasonography is one of the simplest and commonly used methods for evaluation of blood flow in flaps. Doppler probe can be used to detect flow of in-depth vessels. It can also differentiate between arterial and venous obstruction. Limitation of conventional Doppler probe is difficulty in separating the signals coming from adjacent normal vessels deep to the flap. Though implantable mini-doppler probes are also available for flap monitoring but they are not much popular in clinical use [7, 8]. Laser doppler study mainly measures skin blood flow and can be used for non-invasive, continuous monitoring of skin flaps. A number of limitations with this technique limit its clinical utility, including sensitivity to position, sensitivity to temperature, shallow penetration and small sample area [9, 10]. Photoplethysmography and near-infrared spectroscopy are methods of flap monitoring, but none of them is commonly used in clinical settings [11, 12]. Measurement of various aspects of flap metabolism have been utilized for monitoring of flaps, in different methods. Measurement of transcutaneous oxygen tension is one of the oldest methods of assessing flap viability. This method is, however subject to many other systemic factors affecting oxygen transport and tissue oxygenation [13]. Continuous pH monitoring is another method of assessing metabolic function in flaps. A rapid fall in pH is suggestive of anaerobic metabolism in flap due to vascular compromise. This method has been successfully used in experimental studies but it has never reached widespread clinical application. Soon after vascular compromise anaerobic metabolism starts in flaps, leads to fall in pH, increase in pyruvate level and fall in glucose level in flap. Flap glucose level measurement can also be used as monitoring of flap metabolism [14]. In our study, we measured flap blood glucose level with glucometer and correlated it clinical changes in flap.

Aims and Objectives

- To study blood glucose level in flaps incorporating skin in comparison to control site
- To correlate flap blood glucose level with clinical changes in these flaps

Materials and Methods

It was a single centre, single arm, non-comparative longitudinal observational study done from May 2019 to October 2020. Institutional Ethics Committee approval has been taken. Informed written consent was taken from all participants. Thirty (31) patients, operated for reconstruction with various flap incorporating skin in the department of plastic and reconstructive surgery after taking informed written consent.

Inclusion Criteria:

- Age – 12 to 60 years
- Patients of both sexes
- All flaps incorporating skin used in reconstructive purpose.

Exclusion Criteria:

- Age - < 12 years and >60 years
- Comorbidities– diabetes mellitus, chronic smokers and tobacco users or patients of vasculitis or any other vasculopathy
- Not ready to give consent or willing to participate

Technique of Flap Glucose Monitoring: Flap blood glucose levels have been measured at scheduled times by glucometer. At the same time blood glucose levels has been measured from adjacent normal skin (control site). In addition to blood glucose assessment simultaneous clinically findings have been noted and correlated.

In the event of any indication of impending/frank ischemic changes appropriate measures have been taken by the surgeon in-charge.

Capillary blood sample has been taken by pin prick method at the distal most part of flap. At the same time patient blood glucose level has been measured from normal skin adjacent to flap.

Timing of Flap Blood Glucose Monitoring: Samples were taken in immediate post-operative period then after 1hr, 12 hr, 24 hr, 48 hr and 72 hr after operation.

Methods of the Clinical Evaluation: Flaps have been examined clinically at the same time by following parameters to assess the viability of the flap.

1. Skin colour
2. Capillary refill
3. Oozing on pin prick
4. Comparison of flap temperature with normal adjacent skin

All data collected entered into Microsoft Excel 2010 spreadsheets and analysed using SPSS version 20.0, Student's t- test was used to assess significance between mean glucose level of healthy and ischemic flaps. ROC curve analysis was used to determine a cut-off value of blood glucose level.

Results

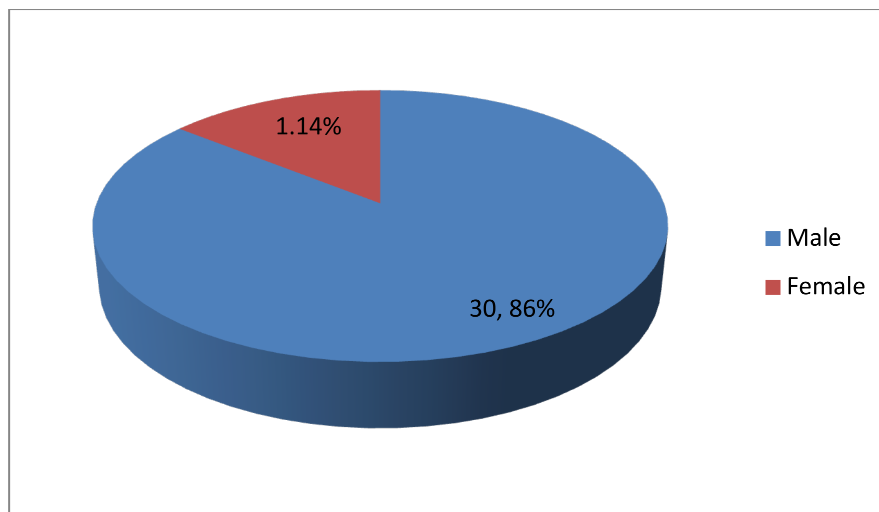
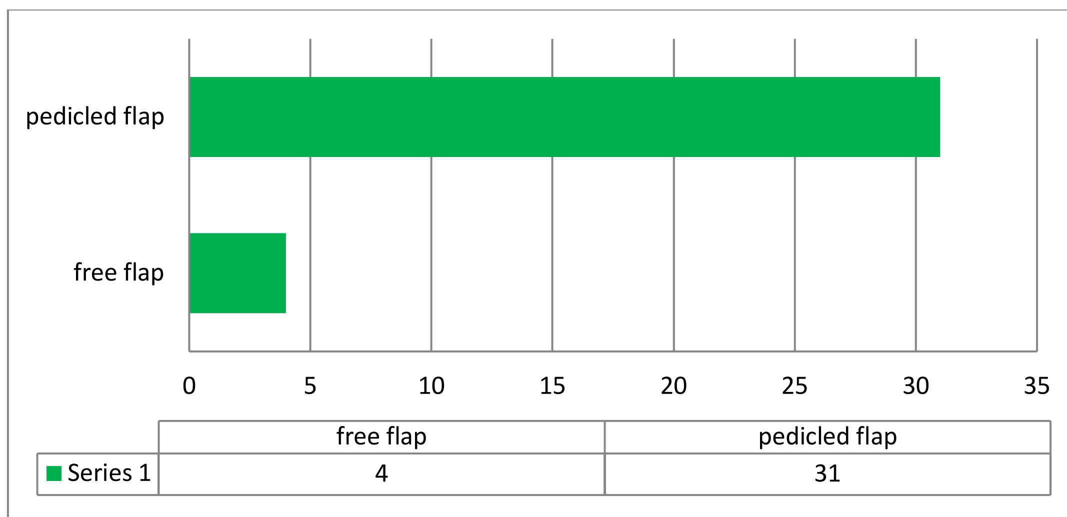


Figure 1: Sex distribution among the study participants

Sex distribution of patients included in the study where it is shown that majority of the study population 30 (86%) was male and female constituted 14% [Fig. 1].



	free flap	pedicled flap
Series 1	4	31

Figure 2: Distribution of types of free flap in this study

Distribution of flap types in the study where total of 31 flaps was pedicled flap and 4 flaps were free flaps [Fig. 2].

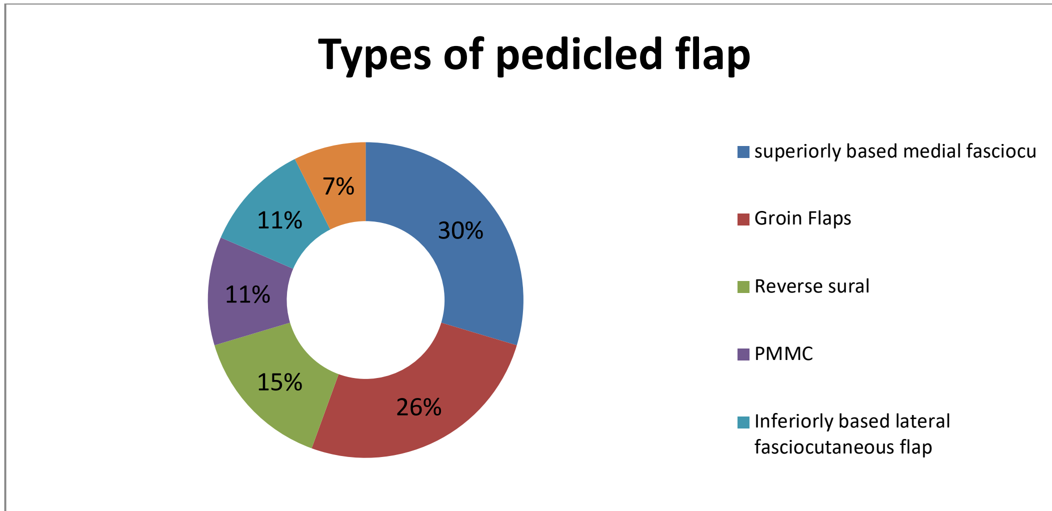


Figure 3: Distribution of types of pedicled flaps in the study

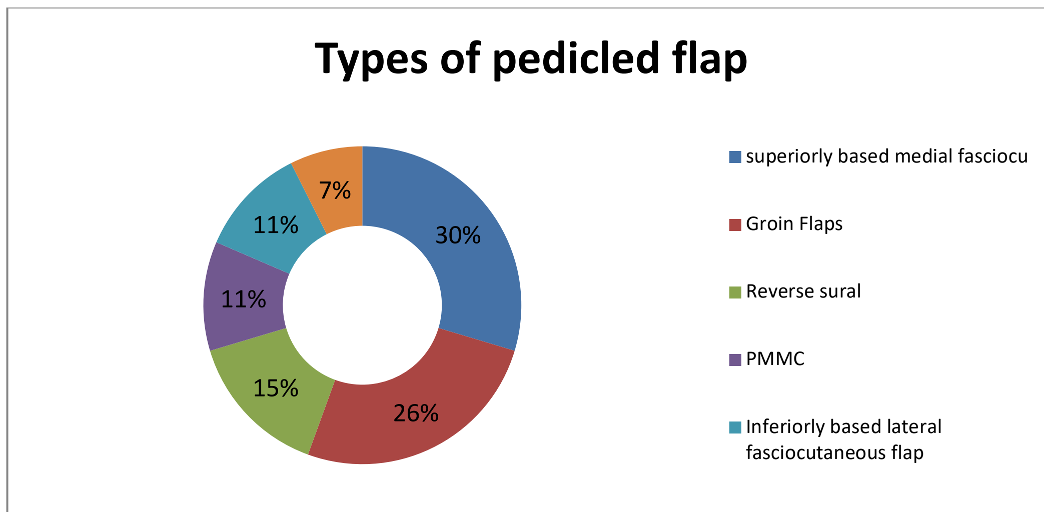


Figure 4: Distribution of types of pedicled flaps in the study

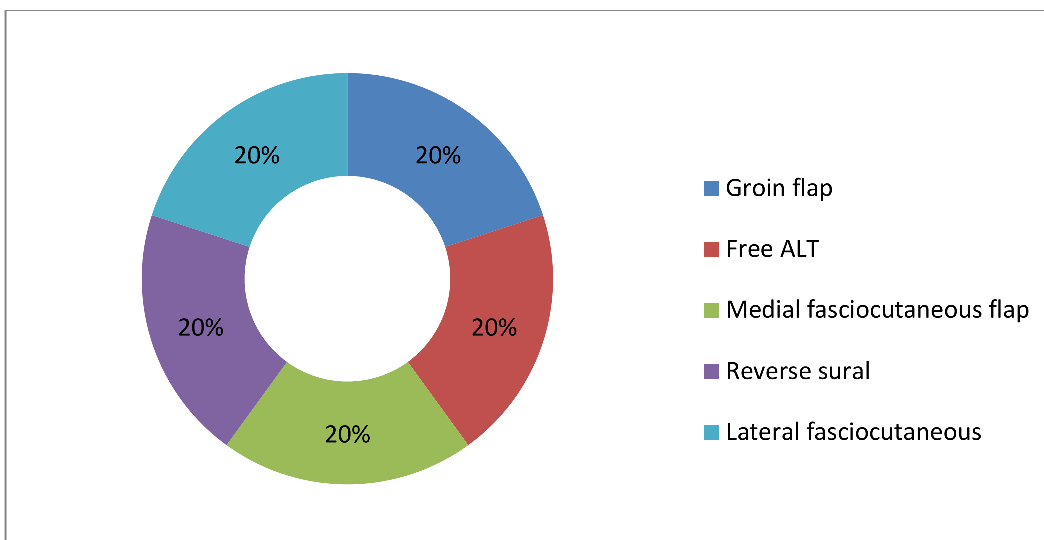


Figure 5: Distribution of operations for various indications of reconstruction with flaps incorporating skin

In this study, thirty-five patients have been included who have been operated for various indications of reconstruction with flaps incorporating skin (cutaneous, fasciocutaneous, myocutaneous and osteomyocutaneous flaps). Flaps without skin like muscle flap, adipofascial flap and free bone transfers have not been included in the study. Out of thirty-five patients, thirty were male and five were female. Among four free flaps, three were antero-lateral (ALT) fascio-cutaneous flap and one was free latissimus dorsi (LD) musculocutaneous flap [Fig. 5].

Out of thirty-one pedicled flaps, there were eight superiorly based medical fascio-cutaneous flaps of leg, seven groin flaps, four reverse sural, three pectoralis major myocutaneous flaps (PMMC), three inferiorly based lateral fasciocutanous flaps, two inferiorly based medial fascio-cutaneous flaps, two deltopectoral flap (DP), one midline forehead flap and abdominal flap. We have measured flap blood glucose and body blood glucose from control site simultaneously and then calculated flap blood glucose as a percentage of body blood glucose. Out of 35 flaps, 21 flaps have done well and no sign of ischemia was found in these flaps. Blood Glucose levels of these flaps were taken at regular intervals as per study schedule.

Among 35 flaps, 9 flaps have shown signs of ischemia clinically at some points. One free ALT flap, one groin flap, one reverse sural, one lateral fasciocutaneous and five medial fasciocutaneous flaps have shown ischemia in the study at some point of time. Blood glucose values of these flaps also taken as percentage of body blood glucose. In these flaps blood glucose level has shown a declining trend continuously, if no intervention has been taken to salvage the flap. Total 63 values have been recorded from clinically ischemic flaps. Blood glucose values of ischemic flaps were significantly low with a mean value of 35.81% of body glucose.

Blood glucose level in normal flap initially declined slightly in comparison to body glucose level, but show rising trends later on. In contrast ischemic flap showed continuous decline in blood glucose level. One case of free ALT flap has been re-explored on the basis of low blood glucose level though clinical signs were unequivocal in flap. On re-exploration vein thrombosis was detected and re anastomosis of vein was done. After re anastomosis of vein, blood glucose level of flap had increased up to normal flap level. These findings suggest early fall of flap blood glucose before appearance of clinical signs of ischemia. All other ischemic flaps could not be salvaged even after surgical intervention. These flaps have shown a continuous decline in the blood glucose levels and clinical changes of ischemia. This suggests a direct correlation of flap blood glucose level with flap ischemia.

Student t test was used to compare blood glucose levels of ischemic flap with normal flap. The mean blood glucose level in congestive or ischemic flaps was significantly lower than the healthy flap. Table 1 shows the difference between mean blood glucose of healthy and necrosed flaps at serial interval. At the intervals of immediate, 1hour, 6-hour, 24-hour, 48-hour, 72 hour, 5 days the mean values of glucose are lower in necrosed flap than survived flaps. It was found to be statistically significant ($p<0.05$) [Table 1].

Table 1: Difference mean glucose values across flaps

Categories	Flap status	N	Mean	Std. Deviation	P value	95% CI Lower limit	95% CL Upper limit
Flap immediate glucose value	survived	21	108.19	12.987	0.000	11.10	33.05
Flap glucose value at 1 hour	survived	21	109.43	12.388	0.002	8.01	31.43
Flap glucose value at 6hr	survived	21	107.67	12.060	0.000	13.35	33.09
Flap glucose value at 24hr	survived	21	108.05	14.736	0.000	13.23	37.08
Flap glucose value at 48hr	survived	21	106.43	11.509	0.008	4.87	29.54
Flap glucose value at 72hr	survived	21	109.38	12.237	0.02	2.74	29.35
Flap glucose value at day 5	survived	21	115.86	8.416	0.026	2.26	32.11

ROC (receiver operating curve) analysis was used to determine a cut off value of body blood glucose at immediate, 1 hour, 6-hour, 24-hour, 48-hour, 72-hour, and Day 5. The characteristic of other cut-off values is shown Fig. 6.

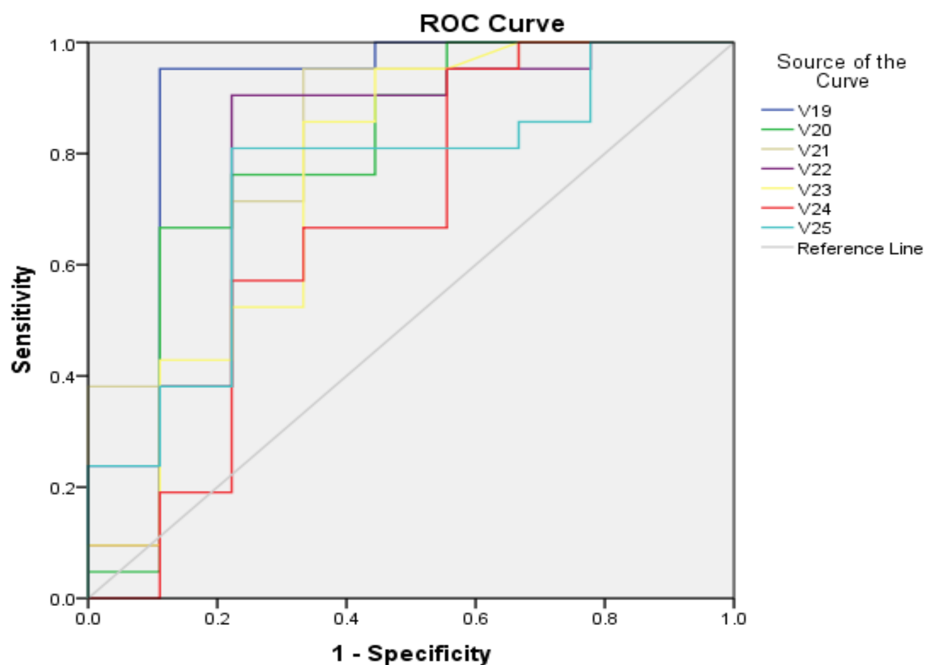


Fig. 6: ROC (receiver operating curve) analysis of body blood glucose at immediate, 1 hour, 6-hour, 24-hour, 48-hour, 72-hour, and Day 5

Table 2: Area under the curve of glucose values at different interval

Area Under the Curve					
Glucose values at different interval	**Area**	**Std. Error[a]**	**Asymptotic Sig.[b]**	**Asymptotic 95% Confidence Interval**	
				Lower Bound	**Upper Bound**
Immediate	0.899	0.082	0.001	0.740	1.000
1 hour	0.794	0.105	0.012	0.589	0.999
6 hour	0.815	0.092	0.007	0.634	0.995
24 hour	0.788	0.109	0.014	0.575	1.000
48 hour	0.759	0.111	0.027	0.542	0.976
72 hour	0.672	0.124	0.141	0.428	0.916
Day 5	0.746	0.101	0.035	0.548	0.944

Table 3: Flap glucose at various interval

Flap Glucose at various interval	Cut off value (% of body blood glucose level)	Sensitivity (%)	Specificity (%)
Immediate	75	95	90
1 hour	66	90	60
6 hour	70	95	70
24 hour	75	95	70
48 hour	70	95	60
72 hour	75	95	60
Day 5	79	95	60

Discussion

The results of our study show that blood glucose level is reduced initially in all flaps and show a rising trend in healthy flap, but remain slightly low even after 72 hours. Blood glucose level of ischemic flaps shown continuous fall and correlate well with the clinical changes of ischemia. Fall in blood glucose level of flaps can be explained by reduced blood supply of flaps, as blood supply of flaps, come from a single direction. In these conditions of relative ischemia, various adaptive mechanisms, like opening of choke vessels, start in flaps, and help them to survive. These mechanisms are responsible for rise in blood flow and blood glucose level of flaps.

We have also found blood glucose measurement (BGM) an easy to use and efficient adjunct for monitoring post-operative blood flow in flaps and may help in determining whether rescue of the flap is needed. A decrease in the blood glucose levels in congestive flaps has been reported in several studies. Benjamin E Cohen et al 1982 studied glucose metabolism in rat abdominal skin flaps in an experimental study. Skin biopsy has been from the flaps during the first 3 days after the flap elevation. Author finds a marked increase in glucose consumption and lactate production in flaps compared to normal skin [15]. Sitzman TJ et al (2010) had conducted an experimental study in a rodent model to assess intestinal glucose changes after vascular occlusion of flaps. They had found significantly lower level of intestinal blood glucose after occlusion of vessels [16].

Sakakibara et al described the first use of a blood glucose metre for flap monitoring in diabetic patients and detected low glucose levels in congested flaps [17]. Hisako hara et al (2010) used blood glucose measurement for flap monitoring by using simple glucometer, which was commonly used for diabetic patients. Author had found low glucose level in congested flaps and suggested a cut-off value for BGM of 62 mg/dl with sensitivity and specificity 88% and 82% respectively by using ROC curve analysis. They have not mentioned the effect of fluctuating blood glucose on flap blood glucose level [18].

In our study we have also found low level of blood glucose in clinically congested flaps. Blood glucose level of control site has been taken with flap blood glucose level and flap blood glucose measurement was derived as percentage of control site BGM. We have found significant decrease in BGM of congested flaps in comparison to normal flaps. On the basis of ROC analysis, we suggest a cut off value for flap BGM of 62% of control site blood glucose measurement. At this value sensitivity and specificity were 100% and 99% respectively.

As BGM has been taken as a percentage of control site BGM, its fluctuations with very high or low body blood glucose level are not expected. Its resistance to fluctuate with body blood glucose level make percentage BGM more valuable and even it can be used in diabetic patient, though diabetic patient has not been included in this study. The mechanism involved in the reduction of blood glucose is unclear, but result in animal study suggest two mechanisms, shortage of blood supply and anerobic metabolism of fat [16].

Shirin P et al study (2024) had demonstrated that the mean glucose levels were significantly higher in the survival group (134.46 mg/dL) compared to the non-survival group (55.38 mg/dL) in patients undergoing flap surgeries. Glucose levels in the survival group remained consistently elevated, whereas they declined in the non-survival group. Statistical analysis showed a significant difference ($p<0.001$) between the mean glucose levels of the two groups. All flaps with complications exhibited changes in color, turgor, and pin prick bleeding. This suggests that higher glucose levels within the flap tissue are indicative of adequate perfusion and metabolic activity [19]. Both venous congestion and ischemia reduce blood supply to the flap, which causes a shortage of glucose supply and leads to hypoglycemic state in flaps. In addition, decreased blood supply to flap causes hypoxia, which results decline in aerobic metabolism and increase in anaerobic metabolism. Acceleration of anaerobic glycolytic pathway augments flap hypogycemia and increases lactate production. This proposal is supported by the fall in the blood glucose level and faster rise in the lactate level in ischemic conditions in experimental studies [20].

In this study flap has been salvaged with early intervention (re-exploration and revision of anastomosis of veins) on the basis of low BGM, though clinical parameters were not clearly suggestive of ischemia. Sitzman TJ et al had shown that fall in blood glucose occur within 30 mins of vessel occlusion. In comparison clinical changes of ischemia/congestion usually comes after hours of vessel occlusion, though exact time varies from tissue to tissue. All above mentioned things suggest early fall of BGM than onset of clinical signs of ischemia/congestion [16]. On the basis of our study, exact difference between fall in BGM and onset of clinical signs cannot be commented as BGM monitoring was not continuous. Though continuous blood glucose monitoring can be ideal monitoring method but its practical acceptability is questionable.

In few flaps blood amount was not sufficient for reading in glucometer on pin. These flaps were not included in the study and monitoring of these flaps were solely on clinical methods. Insufficient bleeding on pin prick is one of the limitations of BGM in the monitoring of flaps by glucometerr. Multiple puncture sites for BGM assessment can be hazardous for flaps though no flaps were lost in our experience by this method. In this study, depth of puncture was restricted upto dermis level, hence safety of flap ensured. The BGM method described here is simple and can be performed by residents, nurses and patients themselves by using the current flap monitoring instruments. Being a quantitative method BGM has no subjective variability as in clinical monitoring methods, hence especially useful for learners. BGM may also be useful for monitoring flaps where clinical monitoring is difficult as in intraoral flaps.

Conclusion

On the basis of this study, it can be concluded that Blood glucose level of all healthy flaps decreases initially and start to rise after 24 hours but remain slightly lower than normal blood glucose level upto 72 hours. Blood glucose levels of flaps decrease significantly in case of congestion or ischemia of flaps and correlate well with clinical changes and keeps on falling if no intervention is taken. Fall in blood glucose can be used as an early indicator of flap ischemia and provide opportunity to salvage flaps. As a percentage of body blood glucose levels flap BGM is more reliable and resistant to function in body glucose levels, and can be used in diabetic patients. On the basis of ROC curve analysis, we suggest a cut off value of 62% of the body glucose as a reliable indicator of flap ischemia with sensitivity and specificity 100% and 99% respectively. Blood glucose measurement (BGM) is an easy, accessible and objective method of flap monitoring, combination of BGM with clinical monitoring methods is likely to reduce postoperative complications of flap congestion.

Limitations

Adequate blood for blood glucose assessment on pin prick is the major limitation of this method. The major disadvantage of this method is that it required puncture for serial monitoring of flaps.

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