Article published online: 2023-06-01

Role of Lactate Measurement in Flap Monitoring: An Useful Adjunct

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Indian J Plast Surg 2023;56:344–349.

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Abstract

Background Detection of vascular compromise in flap is often a challenging task for reconstructive surgeons. A timely salvage procedure depends on objectivity and reliability of postoperative flap monitoring. This study determined if flap capillary lactate helps in prediction of flap viability in first 48 postoperative hours of surgery.

Methods We conducted this study on all flaps with accessible skin paddle where capillary lactate values were assessed along with clinical observation to check viability of flap at 0, 1, 6, 12, 24 and 48 hours of surgery. The data was statistically analyzed for significance and area under the receiver operating characteristic curve was used for calculating cutoff value for lactate.

Results Out of a total of 30 patients included in this study, 25 were males and the mean age was 45.03 years. Fifteen patients underwent free flap and rest pedicled. Highly significant association of role of clinical observation in the outcome of flap was found. The average of lactate values for survived and distally ischemic flap was 5.32 ± 1.91 and 8.38 ± 1.81, respectively, which was highly significant. The cutoff value of lactate below which all flaps survived was found to be 6.09 mmol/L.

Conclusion Flap capillary lactate measurement is an easy, quick, cost-effective, and objective tool for checking viability of flaps.

Keywords
- flap capillary lactate
- flap ischemia
- free flaps
- flap monitoring
- vascular thrombosis of flap

Introduction

Worldwide, the flap failure rate ranges from 2 to 5%[1] the most common cause of which is vascular thrombosis (15–73%).[2,3] It has been observed that early detection of vascular compromise and timely intervention can decrease the rate of flap failure, thus highlighting the importance of accurate postoperative flap monitoring.[4]

Ideal flap monitoring tools should be objective, reliable, sensitive, and simple.[5] Though clinical observation[6] is still the gold standard technique for flap monitoring, the search for a less subjective tool is never ending. Any technique capable of detecting altered flap physiology, before clinical deterioration, will be a very useful tool for salvaging the flaps. We know that all hypoxic cells in the body undergo anaerobic metabolism, thereby producing lactate.[7,8] Thus, all flaps with ischemia are expected to have a rise in lactate levels. This study was planned to assess the reliability of the flap blood lactate value in predicting the viability of the flap during the first 48 postoperative hours of flap surgery.

Materials and Methods

This prospective study was conducted on patients admitted to the Department of Plastic and Reconstructive Surgery in a

article published online
June 1, 2023

DOI https://doi.org/10.1055/s-0043-1769111.
ISSN 0970-0358.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

tertiary care hospital in Punjab from February 2020 to August 2021. After approval from Institution Ethical Committee (IEC), all consenting patients who underwent any type of flap surgery with an accessible skin paddle were included. All diabetic and critically ill patients were excluded from the study as they have altered metabolic metabolism in their bodies. The IEC did not approve the inclusion of children and pregnant ladies in the study.

The flap skin paddle was used for flap prick assay and clinical monitoring.

The first postoperative flap examination was recorded immediately after surgery. Measurements for capillary lactate were made with the device (lactate- ProTM). The blood drop required was obtained with disposable diabetes lancing device or a 25G needle. The most distal margin of the skin paddle was chosen for lactate prick test. Clinical examination included color and temperature, capillary refill time, and bleeding characteristics with a pinprick.

During postoperative period, clinical examination was done hourly, and flap lactate levels were measured and recorded at 0, 1, 6, 12, 24, and 48 hours. A record of clinical observations during the same intervals was also made. The decision of any salvage procedure was made only on a clinically compromised flap.

The data, thus, collected was expressed in terms of a frequency distribution (number of cases) and relative frequencies (percentages) as appropriate and mean ± standard deviation (±). Chi-squared analysis was performed to check the level of significance. A *p*-value less than 0.005 was considered significant. Receiver operating curve analysis was done to assess the specificity and sensitivity of lactate in flaps. All statistical calculations were done using SPSS (Statistical Package for the Social Science) 21 version statistical program for Microsoft Windows

Results

Over a period of 19 months (February 2020 to August 2021), 30 patients fulfilling all inclusion criteria were included in the study, with a mean age of 45.03 years and males (83.3%) outnumbered females (►**Table 1**) Out of 15 free flaps in the study, each free flap had undergone one arterial anastomosis and one or two venous anastomoses. No vascular bridge was needed in any of the free flaps. There were 15 pedicled flaps in the study.

We observed that 22 patients had no flap-related complications (73.34%; ►**Table 2**); all patients had clinically healthy flaps at 0 and 1 hour, respectively and noticeable distal ischemia was seen in two flaps at 6 hours, six flaps at 12 hours, seven flaps at 24 hours, and eight flaps at 48 hours. Statistical analysis implicated highly significant association of the role of clinical evaluation in the outcome of flap at *p*-value less than 0.005 (►**Table 3**). All the flaps survived at 0 hour and 1 hour without any variation in an average value of lactate, that is, 6.13 ± 2.30. Variation within the groups was observed by applying analysis of variance suggestive of highly significant correlation ($p < 0.001$) initially at 0 hours in various outcomes of flap survival. But nonsignificant correlation was found at 1 hour and 6 hours levels of measured lactate for flap survival. On the contrary, highly significant correlations ($p < 0.005$) were observed with time evolution in flaps that survived up to 48 hours (►**Fig. 1**). The average values of lactate in the survived and distally ischemic flap outcome were 5.32 ± 1.91 and 8.38 ± 1.81, respectively, which was highly significant *p* less than 0.005. Using these thresholds, the characteristics of the test assessed by receiver operating characteristic (ROC) analysis shown below would be sensitivity = 100% and specificity =68.2% (►**Fig. 2**). In spite of the low sample size, we were still able to demonstrate that lactate exceeded the threshold level before clinical deterioration. The rising trend of capillary lactate as compared with clinical observation at different time intervals is shown in ►**Table 4**.

►**Fig. 1A** shows lactate levels of a patient were radial artery forearm flap was done for an intraoral defect.

Thus, this study suggested that the values of lactate measured were found to be below 6.09 mmol/L in 15 out of

Table 1 Frequency distribution of cases according to wound site, types of flaps, and complications

Wound site	No. of cases
Intra oral cancer	18
Post electric burn hand	1
Posttraumatic wound leg/foot	4
Sacral pressure sore	1
SCC of foot	1
Posttraumatic/amputation wound to upper limb	4
Gluteal pressure ulcer	1
Type of flap	**No. of cases**
Cross leg flap	2
Free ALT flap	5
Free fibular flap	4
Free LD flap	1
Free radial artery flap	5
Gluteal flap	2
Groin flap	4
LD pedicled flap	2
PMMC flap	4
Reverse sural artery flap	1
Flaps with distal ischemia	**No. of cases**
Cross leg flap	1
Free ALT flap	2
Free LD Flap	1
Gluteal flap	2
PMMC flap	1
Reverse sural artery flap	1

Abbreviations: ALT, antero lateral thigh; LD, lattismus dorsi; PMMC, pectoralis major myocutaneous; SCC, squamous cell carcinoma.

Table 2 Frequency distribution of flaps according to clinical observation at various time intervals

		Outcome of flap at 0 hours	Outcome of flap at 1 hours	Outcome of flap at 6 hours				Outcome of flap at 12 hours				Outcome of flap at 24 hours				Outcome of flap at 48 hours				
		Number of patients survived	Number of patients survived	Number of patients		Chi-squared value	*p*-Value	Number of patients		Chi-squared value	*p*-Value	Number of patients		Chi-squared value	*p*-Value	Number of patients		Total	Chi-squared value	*p*-Value
				Ischemic	Survived			Ischemic	Survived			Ischemic	Survived			Ischemic	Survived			
Color	SAS	30	29	2	4	8.357	0.034	0	20	15.000	0.001	0	20	18.261	0.001	1	22	23	25.109	0.001
	Changed	0	1	0	24			6	4			7	3			7	0	7		
Capillary refill	Normally delayed	30	30	1	24	14.571	0.001	2	23	15.375	0.001	1	22	24.653	0.001	2	22	24	20.625	0.001
	Delayed	0	0	0	4			1	1			0	1			0	0	0		
	Immediate	0	0	0	0			0	0			0	0			0	0	0		
	Abnormal	0	0	1	0			3	0			6	0			6	0	6		
Bleeding characteristics	Arterial	29	25	0	18	30.00	0.0001	0	19	21.07	0.0001	0	20	21.48	0.0001	0	22	22	30.00	0.0001
	No bleed	0	0	2	0			4	0			6	1			8	0	8		
	Venous	1	5	0	10			2	5			1	2			0	0	0		
Temperature	Warm	30	28	0	22	5.893	0.064	0	22	20.625	0.0001	0	20	18.261	0.0001	0	22	22	30.00	0.0001
	Cold	0	2	2	6			6	2			7	3			8	0	8		
Total		30	30	2	28			6	24			7	23			8	22			

Abbreviation: SAS, same as surrounding skin.

Table 3 Value of lactate measurements at various time intervals

Final outcome of flap	Survived ($n=22$)		Ischemic ($n=8$)		Z	*p*-Value
Lactate	Mean	SD	Mean	SD		
At 0 hours	2.20	0.69	3.83	1.63	−3.901	0.001
At 1 hours	4.77	2.14	6.18	2.33	−1.554	0.131
At 6 hours	6.17	2.82	9.73	3.95	−2.742	0.011
At 12 hours	7.14	3.18	13.52	2.39	−4.554	0.000
At 24 hours	6.41	2.68	13.50	0.71	−3.664	0.001
At 48 hours	5.20	2.67	15.00	–	−3.591	0.002
Average	5.32	1.91	8.38	1.81	−3.941	0.000

Abbreviation: SD, standard deviation.

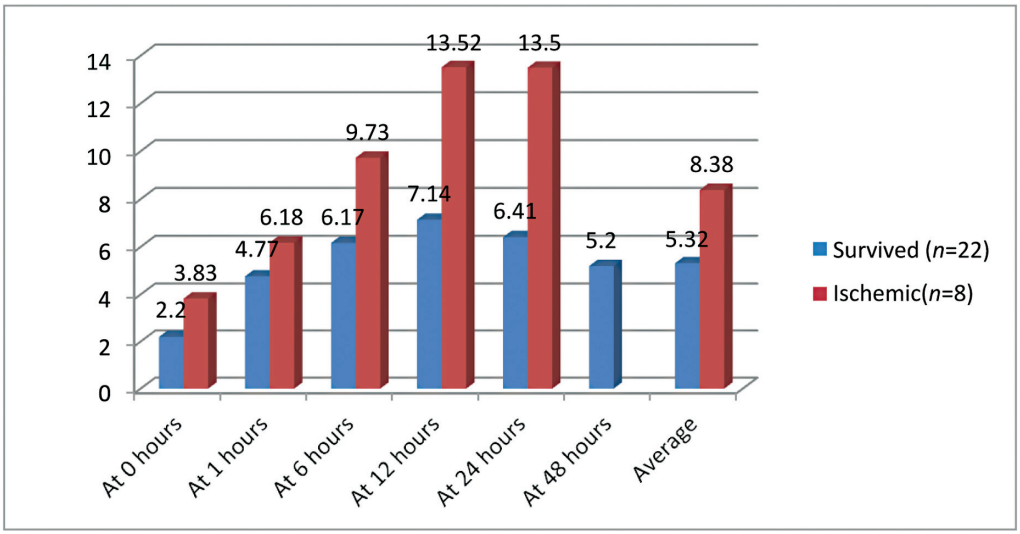

Fig. 1 Values of lactate measurements in survived and distally ischemic flaps.

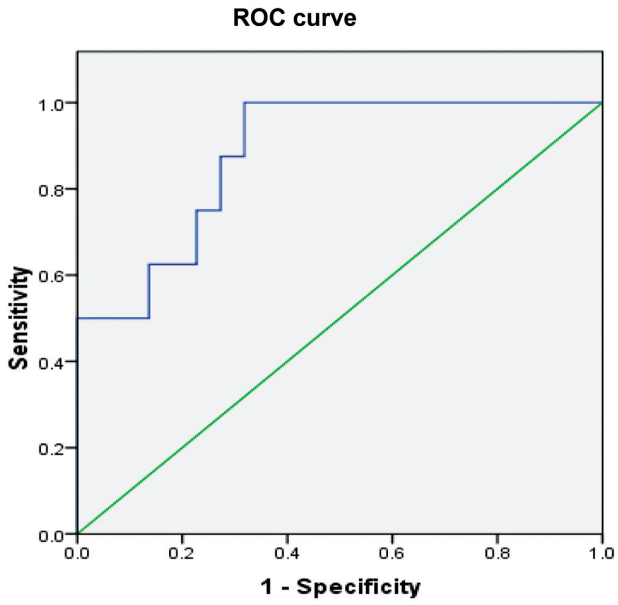

Fig. 2 Receiver operating characteristic (ROC) curve of lactate value in predicting survived and distally ischemic flaps.

22 survived flaps, whereas values were above 6.09 mmol/L in all the 8 distally ischemic flaps as shown above in ►**Fig. 3**. Thus, it suggests a significant association of the measurement of lactate levels at a cutoff value of 6.09 mmol/L with the survival of flap, which means that values less than 6.09 are 100% sensitive for predicting a viable flap. On calculating the Youden Index on ROC curve, 100% specificity was achieved at values above 9, which is critically alarming for nonsurvival of the flap.

Discussion

The purpose of any technique for flap monitoring is to detect perfusion failure and establish the need for a timely surgical intervention before irreversible tissue damage appears. The salvage rate of flaps has been reported to be inversely related to the time interval between the onset of pedicle impairments and their clinical recognition.[9] Clinical examination still remains the cornerstone of flap monitoring and is considered by most surgeons to be the gold standard technique.[6] Though clinical examination remains the most frequently used, yet it is the least reproducible and a

Table 4 Trend of lactate measurement and clinical observation at various time intervals

S.no	Color		Capillary refill		Bleeding characteristics		Temperature	
	Hours	Lactate value	Hours	Lactate value	Hours	Lactate value	Hours	Lactate value
1	12	9.1	–	–	12	9.1	24	14
2	6	14	–	–	6	14	6	14
3	1	9.2	12	14	1	9.2	1	9.2
4	6	10.2	24	16	6	10.2	6	10.2
5	12	14	12	14	6	12	6	12
6	6	7.6	24	13	6	7.6	6	7.6
7	12	14	24	16	0	6.8	1	7.1
8	6	14	6	14	1	6.1	6	14

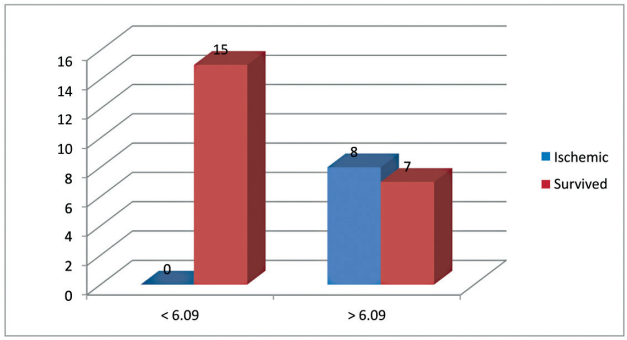

Fig. 3 Bar graph showing mean value of lactate in survived and distally ischemic flaps.

subjectively variable technique[6] as it depends on the evaluator experience.[10] All flaps where ischemia is occurring are expected to have increased in lactate levels. Thus was this study an attempt to measure and interpret flap's lactate value. On recording of capillary lactate in these patients, we observed that it was raised in all compromised flaps. The average lactate value in survived and distally ischemic flaps was 5.32 ± 1.91 and 8.38 ± 1.81 respectively. There was a significant association of lactate levels at a cutoff value of 6.09 mmol/L with the survival of flap. Several studies have been published on cutoff lactate values in flaps with impeded blood flow.[9,11,12] Jyränki et al[11] reported that the lactate values in flaps without impeded blood flow were less than 7 mmol/L, whereas Henault et al[9] used more than 6.4 mmol/L as the cutoff value. Our cutoff blood lactate value was close to the critical value reported by Henning et al[7] and Bakker et al,[8] in critically ill patients.

Another similar blood indicator is flap glucose levels that are shown to be less than those of body in an ischemic flap.[13] However, literature supports that the lactate value increases first, followed by the decrease in blood glucose value.[14] Values of flap glucose are less reliable in diabetic and hepatic dysfunction patients. Moreover, the amount of blood required for lactate measurement is lesser than the amount needed for capillary glucose measurement.[15]

Many previous studies[12,13,16] used microdialysis measured blood lactate values inside the flap tissue. Microdialysis is a method used during surgery where a catheter is embedded in the flap tissue (e.g., skin, muscle, or fat) to measure the target substance. This allows for continuous measurement and excellent objectivity especially for buried flaps, but at the same time is a complicated procedure and needs an experienced personal for its management.[11]

Our study cited the major advantage of this instrument as its ability to measure capillary lactate very quickly and easily.

In our study, two of the ischemic-free antero lateral thigh (ALT) flaps were reexplored at 12 hours and 24 hours at lactate value of 15 and 14 mmol/L and veins were redone. Both these flaps survived. One of the ischemic-free lattismus dorsi (LD) flap was reexplored at 6 hours at lactate value of 14 and flap did not survive in spite of redoing both artery and vein. Two of ischemic pedicled gluteal flap flaps had distal necrosis where release of distal flap margin was done at 12 hours and 24 hours at lactate value of 13 and 14 mmol/L, respectively. In other ischemic flaps, the lactate levels were raised at distal most margins that were secondarily excised and skin grafted later.

We strongly believe that this simple measuring instrument can be used to obtain objective information quickly and easily in cases where an inexperienced observer is unsure of whether blood flow is impeded based on clinical findings. In such instances, the cutoff values reported in past studies[11,12] and in this study can be a good reference. Nursing staff can easily and repeatedly measure flap lactate with lactometer and disposable strips. Indeed, previous studies have shown good accuracy of handheld lactate measuring devices in monitoring lactate levels in critically injured/ill patients.[7,8] Moving forward, we must attempt to determine whether blood flow is impeded by referencing the measured lactate values rather than clinical findings and then performing timely salvage surgery. Accumulating the data when the blood flow is impeded is essential in accomplishing this task.

This study demonstrated that a microsurgeon can be sure of flap survival when the objective value of flap lactate less than 6.09 is told to him by someone whose subjective assessment may be not dependable. It also warrants the need of regular subjective clinical assessment by an expert if the lactate is more than this cutoff, for the decision of timely reexploration.

Conclusion

Flap capillary lactate measurement with lactometer and disposable strips is an easy, quick, portable, and cost-effective technique that helps us to get an objective information on flap survival and early ischemia. Despite the significant outcome, our study was limited by a small sample size and a limited number of flaps comprising both free and pedicled flaps.

Conflict of Interest
None declared.

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