Journal of Advances in Medicine and Medical Research

23(11): 1-11, 2017; Article no.JAMMR.36096
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

Simple Interrupted vs. Continuous Suturing in Abdominal Fascia Closure – A Thermographic Analysis in Rabbits

Odermatt Erich[1*], Blender Bernd[1] and Freytag Christiane[2]

[1]Aesculap AG, Tuttlingen, Germany.
[2]FREY-TOX GmbH, Herzberg, Germany.

Authors' contributions

This work was carried out in collaboration between all authors. Author OE designed the study, approved the protocol, managed the literature search and wrote the manuscript. Authors OE and BB executed the thermographic measurements and validated the results. Author FC executed the surgery and managed the analyses of the study. All authors approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2017/36096
Editor(s):
(1) Georgios Tsoulfas, Assistant Professor of Surgery, Aristoteleion University of Thessaloniki, Thessaloniki, Greece.
(2) Salomone Di Saverio, Emergency Surgery Unit, Department of General and Transplant Surgery, S. Orsola Malpighi University Hospital, Bologna, Italy.
Reviewers:
(1) Priya Singh Rangey, Gujarat University, India.
(2) Vincenzo Domenichelli, Infermi Hospital, Italy.
(3) Eghon Guzmán, Hospital Dr. Sotero del Rio, Chile.
Complete Peer review History: http://www.sciencedomain.org/review-history/21068

Original Research Article

Received 12th August 2017
Accepted 1st September 2017
Published 20th September 2017

ABSTRACT

Aims: Thermography is an accepted method in different medical fields to detect and to visualize differences in the blood supply of tissue while following their temperature distribution. In this study, we compare the temperature profile of the simple interrupted vs. the continuous suture technique used for the closure of six rabbit abdominal fascia.
Methodology: The closure of rabbit fascia with a simple interrupted (n=3) or a continuous suture technique (n=3) was implemented, in particular under tension and tensionless conditions simulating possible strain situations for the fascia. The temperature profile of the wound healing process was compared during different operation stages for different tissue layers from the preoperative up to the postoperative period of 21 days followed by histology.
Results: The simple interrupted sutured fascia under 4 N tension experienced a significant

**Corresponding author: E-mail: erich.odermatt@aesculap.de, e.k.odermatt@bluewin.ch;*

temperature drop of 2ºC (P=0,01) for each single suture site as well as for the total suture line and did not achieve the same temperature level as before the application of the strain. On the contrary, the continuous sutured fascia experienced no significant temperature changes under 4 N tensions as well as after releasing the tension.

Conclusion: The thermographic analysis of the two compared suture techniques favored the continuous suture technique for the closure of fascia due to better vascularization and wound healing effects related to a more even distribution of tension across the entire length of the sutured fascia.

Keywords: Thermography; fascia closure; simple interrupted; continuous suturing.

1. INTRODUCTION

The core temperature of homeothermic mammals is preserved in a narrow limit and is a good indicator for the well-being of the organism as well as for certain tissue regions [1]. Classical temperature measurements, e.g. with liquid thermometers have been used for clinical diagnosis but it was Hardy [2] who established the temperature measurement by infrared techniques paving the way for using thermographic analysis for medical indications [3], e.g. in:

- Diabetic neuropathy [4,5]
- Vascular disorders [6]
- Breast cancer [7,8] and liver metastasis [9] detections
- Fever screening [10]
- Thermoencephalopathy [11]
- Rheumatology [12]
- Bowel ischemia [13]

While thermography is routinely used to study topological effects, e.g. in the wound healing of skin and burns [14-16], not much is known about the temperature characteristics of the inner organs or inner surfaces during the healing process, especially of the fascia.

The technique of fascial closure after laparotomy is highly variable among surgeons and may be grouped into two basic methods [17]:

- The layered closure is a sequential closure of each individual fascial layer. Securing wound closure by multiple suture strands is the primary advantage of this method especially if suture dehiscense occurs.
- Mass closure is a continuous fascial closure with a single suture allowing even distribution of tension across the entire length of the suture minimizing tissue strangulation.

Numerous trails found continuous mass closure to be the superior closure method [17]. However, the INSECT trial compared two different continuous suture techniques with an interrupted suture technique finding no significant benefit [18]. In this study we compare the interrupted with the continuous suture technique from the opening of the abdomen until the closure of the fascia with and without applied tension in the preoperative, intraoperative and postoperative status (all day 0) and after 7, 14, 21 postoperative days via thermographic analysis. The objective of the study is to use the tissue temperature and following the effects of the two different suture techniques on the blood supply of the fascia in order to evaluate differences caused by the two suture techniques for the abdominal wall closure.

2. MATERIALS AND METHODS

2.1 Thermographic Equipment and Procedure

Thermal imaging was performed using the infrared camera Fluke Ti45 IR Flexcam Thermal Imager (Fluke Europe B.V., Eindhoven, Netherlands) with a 20 mm objective (F/0.8 8-14 µm JTI-40948-4937) processing mostly 8 to 14 µ infrared emissions. The camera was mounted onto a mobile frame allowing pictures to be taken from 30 cm above the surgery field. The accuracy of the temperature measurement was ± 0.7ºC. The camera was adjusted to a calibrated external thermometer before and after the measurements and remained constant during the application. Three pictures were taken for each treatment step in 20-second intervals, respectively and the 4 N tension was applied for 10 seconds. The operation room temperature remained in the range of 20 ± 0.5ºC. Two persons evaluated all temperature profiles in detail with the Fluke SmartView® software independently. For each fasciae temperature

evaluation more than 20 local points were taken. All values were matched to an average temperature profile presented in Table 2. In general the selection of the temperatures and locations were in very good agreement between the persons. However, the temperature profile had to be reevaluated only for a few discrepancies. T-tests with SigmaStat (Systat Software GmbH, Erkrath, Germany) were used for statistical analysis.

2.2 Surgical Procedure

For the experiment, 6 female specific pathogen free Albino Russian rabbits Crl:CHBB (Charles River Deutschland GmbH, Kisslegg) were used having a body weight ranging from 2.5 to 3.1 kg. The study was approved by the German regional authority of Brandenburg (V3-2347-A-4-2-2011) in compliance with the principle for animal care. Following an acclimatization period of at least 5 days, animals were assigned to 2 different groups comprising 3 animals each at random in order to assess the thermographic procedure. For surgery and thermographic measurements, animals were put under general anaesthesia using ketamine (40 mg/kg) and xylazine (6 mg/kg) intramuscularly (i.m.). Following shaving, cleaning and disinfection of the abdomen, skin incision, preparation of the linea alba, a midline laparotomy of 3 cm was performed. The fascia was closed with Monomax® USP 3-0 (B.Braun) – group 1 with simple interrupted flat knots having a 5 mm interval and a gap of 5 mm to the fascias' edge. In group 2, a continuous suture technique was used having a similar geometry. Thermography was employed for comparing the sutured fasciae. The fasciae were prepared both without tension and with 4 N tension for 10 seconds, the latter to simulate typical stress situations during the healing period. Premilene® USP 0 (B.Braun) was used as the pulling tension suture with a calibrated tensiometer (Chatillon®, Ametek GmbH, Meerbusch, Germany). Details of the procedure are described in Fig. 1.

Intracutaneous suturing (Safil® USP 4-0, B.Braun) and the skin bonding (Histoacryl® B.Braun) were implemented after fascial closure and the thermographic measurements. All thermographic measurements were perfomed at the following time points: preoperative, during surgery for different tissue layers, postoperative after 7 and 14 days and again preoperative, during surgery after 21 days post operationem (post op) and are described in Table 1. The core body temperature was recorded preoperatively, intraoperatively as well as post op. Throughout the experimental period, the animals were caged individually having free access to a pelleted complete diet as well as to drinking water at all times. Enrichment was provided using hay bricks and plastic rings. The study took place in animal rooms provided with filtered air at a temperature of 20°C ± 3°C, with relative humidity being at least 30% and not exceeding 70% as well as with air changes of 10 times/hour. The room was illuminated to give a cycle of 12 hours light and 12 hours darkness. Animals were euthanized after the general anaesthesia using Embutramid (T61, Intervet) intravenously (i.v.) after the last measurements on day 21 post op.

Macroscopic as well as histological examination was performed after 21 days. Samples of the sutured fascia including the sutures were taken for each animal, being put up and fixed in 4% buffered formalin for further embedding, sectioning and staining in Hematoxyline/Eosin.

Table 1. Surgical & thermographical steps of the treatment

Preoperative group 1 & 2	Core temperature measurement
Surgery group 1 & 2	Anesthesia (Ketamine 40 mg/kg, xylazine 6 mg/kg i.m.) Core temperature measurement Shave & disinfection Thermography of abdominal skin Skin incision & preparation of linea alba Thermography of abdominal fascia Midline laparatomy (3 cm) Thermography of abdomen
Surgery group 1	Simple interrupted with loaded individual pulling sutures Individual thermographic measurements for each simple interrupted suture without tension

Preoperative group 1 & 2	Core temperature measurement
	Overall thermographic measurement for simple interrupted closed fascia without tension
	Individual thermographic measurement for each simple interrupted suture with 4 N tension
	Overall thermographic measurement for simple interrupted closed fascia with 4 N tension
	Removal of the pulling sutures
	Overall thermographic measurement for simple interrupted closed fascia without tension
	Intracutaneous suturing and skin bonding
	Thermography of abdominal skin
Surgery group 2	Continuous sutures with loaded pulling sutures
	Overall thermographic measurement without tension
	Overall thermographic measurement with 4 N tension
	Removal of pulling sutures
	Overall thermographic measurement without tension
	Intracutaneous suturing and skin bonding
	Thermography of abdominal skin
Postoperative group 1 & 2	Core temperature measurement
7 and 14 days post op	Sedation (Medetomidin 0.1 mg/kg i. m.)
	Core temperature measurement
	Thermography of abdominal skin wound and linea alba through skin
	Anti-sedation with Atipamezol (0.5 mg/kg i. m.)
21 days post op group 1 & 2	Anesthesia (Ketamine 40 mg/kg, xylazine 6 mg/kg i.m.)
	Core temperature measurement
	Shave & disinfection
	Thermography of abdominal skin and fascia wound through skin
	Skin incision & preparation of linea alba
	Thermography of abdominal fascia
	Autopsy: macroscopical examination
	Histological preparation & fixation
	Euthanasia using Embutramid (T61, Intervet) i. v.

3. RESULTS

3.1 Thermographic Analysis

Exemplary thermographic profiles for both suture techniques are shown with the temperature color frame in Fig. 2. The detailed and adjusted temperature profiles of all operation and time stages are presented in Table 2 as well.

3.1.1 Rectal temperature measurements

Prolonged operation time together with anesthesia result in a typical decrease of the body temperature in small animals like rabbits despite using thermal blankets. This was proven by determining the rectal temperature from approx. 37 to 39ºC to approx. 36 to 38ºC post op for both groups on the day of surgery. Due to differing medication and significantly shorter examination times without incisions after 7 and 14 postoperative days, the temperature remained in the range of approx. 39ºC.

3.1.2 Fascia temperature measurements

Sutures combine separated tissue but it is known that suturing might cause ischemia due to the constriction applied. For this study we employed a three throw knot procedure which was sufficient to adapt the wound edges. The fasciae with the simple interrupted sutures had a temperature profile in the range of 36ºC with higher temperature spots in between indicating some strangulation of tissue leading to hampered blood supply. The continuous sutured fasciae showed a temperature profile of 33ºC. While the continuous suture remained at the same temperature level during the applied tension of 4 N, the simple interrupted technique

displayed a significant drop to approx. 34ºC (P=0.01) which was confirmed by single temperature measurements of each simple interrupted location as well. After releasing the tension, the continuous suture had a similar temperature profile as measured before while the simple interrupted remained at a lower temperature level.

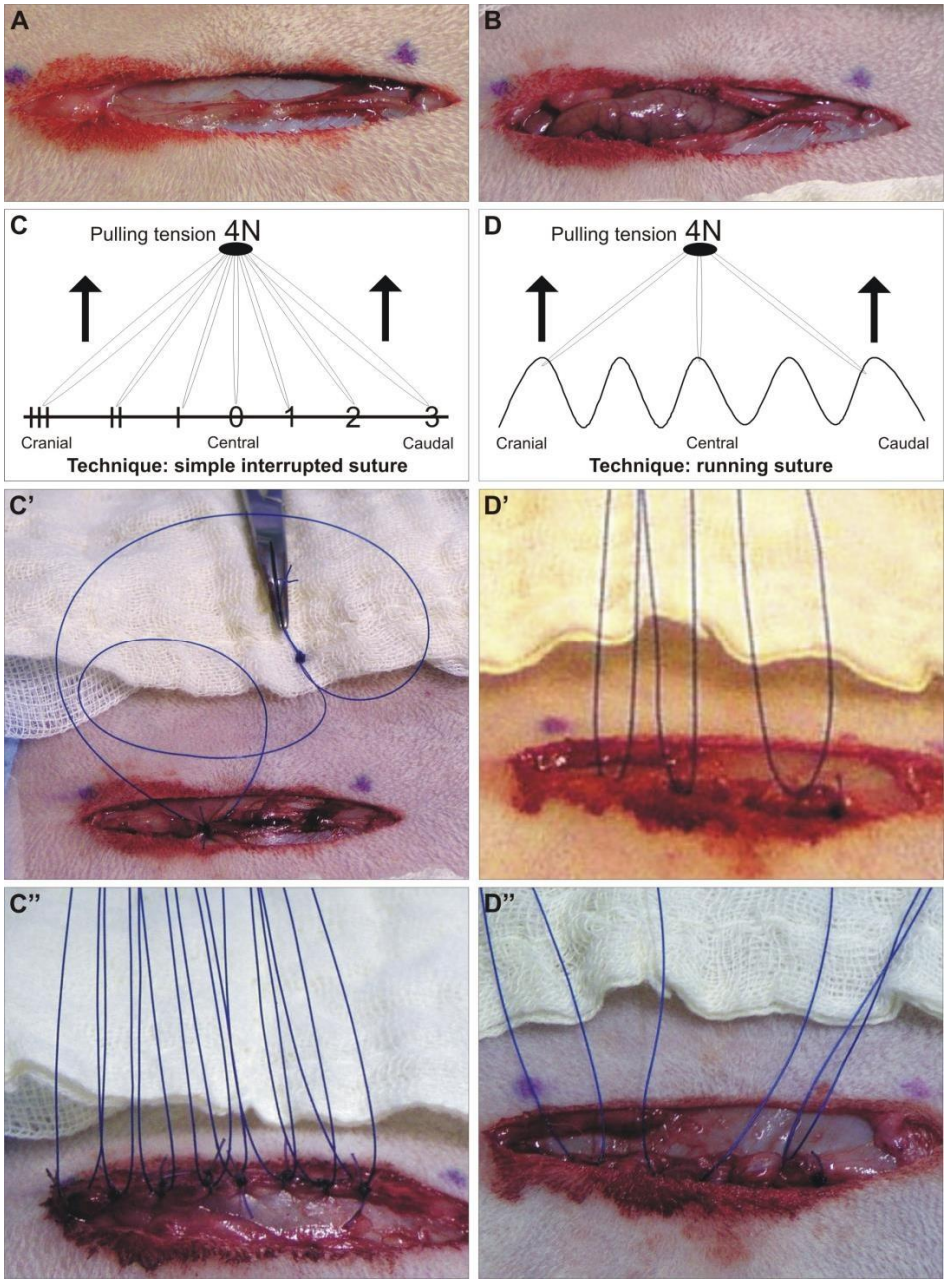

Fig. 1. Applied suture techniques (A) Skin wound, (B) Opened abdominal fasciae with centrally visible bowel, (C) Schematic drawing of the individual simple interrupted suture line with pulling threads for tension application of 4 N, (C´) Placing the central pulling suture (USP 0) under the central simple interrupted suture (USP 3-0), (C´´) All simple interrupted sutures loaded with pulling sutures (USP 0), (D) Schematic drawing of the continuous suture line with pulling threads for tension application of 4 N, (D´ and D´´) Continuous sutures with cranial, central and caudal pulling sutures (USP 0)

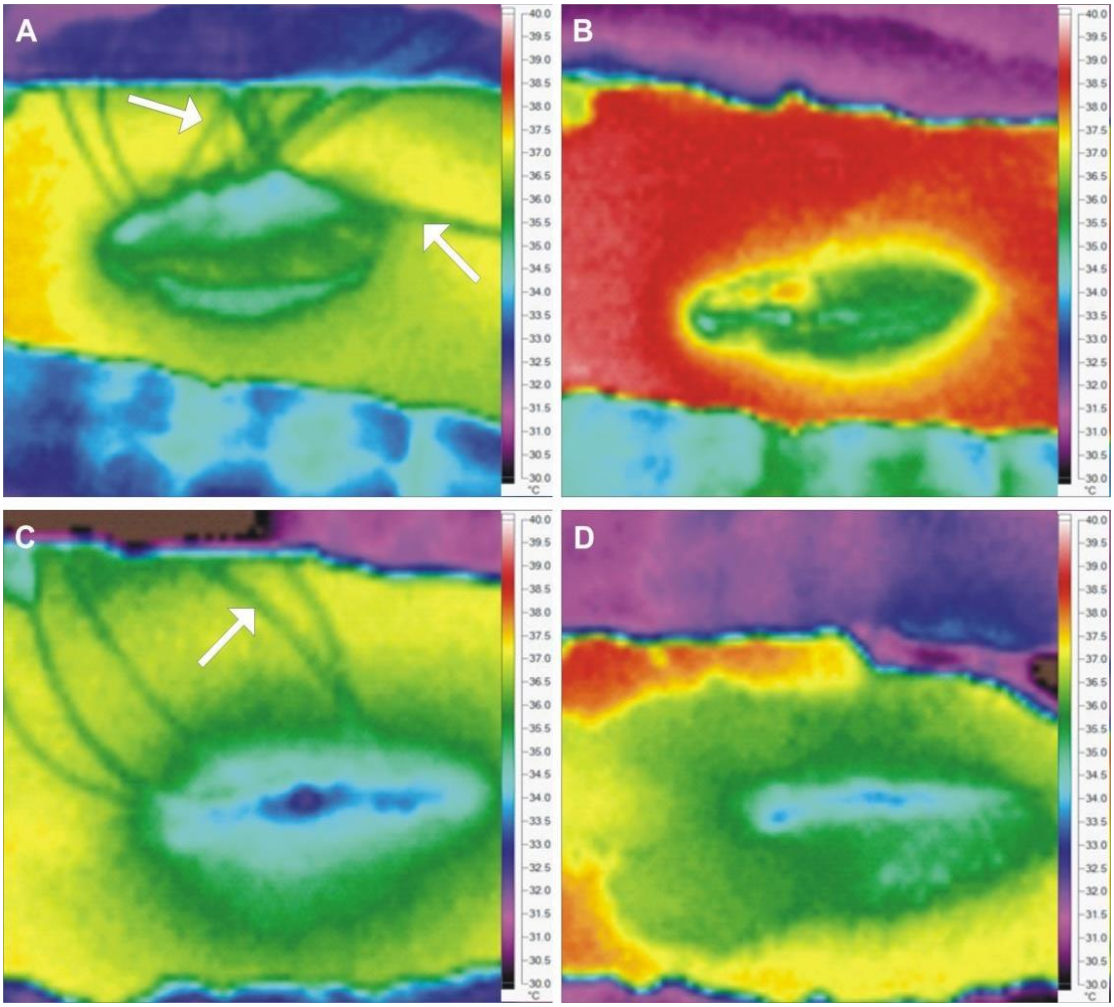

Fig. 2. Exemplary thermographic data of the simple interrupted and the continuous suture technique (A) Exposure of the simple interrupted sutured fascia with placed pulling sutures (→) (B) Simple interrupted sutured fascia after tension relaxation without pulling sutures (C) Exposure of the continuous sutured fascia with loaded pulling sutures (→) (D) Continuous sutured fascia after tension relaxation without pulling sutures

3.1.3 Linea alba temperature measurements

The open and visible linea alba had a temperature profile in the range of approx. 33ºC to 37ºC on the day of surgery and was in good agreement with the open linea alba measurements at 21 days post op. On day 14 and 21, measurements through the skin indicated similar values while a trend for a more physiological temperature in the continuous group seemed to be achieved already after 7 postoperative days. On the contrary, the simple interrupted sutures displayed physiological temperature only after 14 postoperative days.

3.2 Macroscopical and Histological Observations

In order to exclude an influence of the additional examinations in the animals (e.g. additional temperature measurements, tissue stress and anesthesia), a macroscopic and microscopic examination was performed. Recomparison to former histological suture studies revealed no anomalies and indicated physiological healing processes typical for sutured wounds as can be seen in Figs. 3 and 4 [19].

The formalin-fixed tissue samples from each test animal were sectioned and assessed by a board

certified pathologist for inflammation, fibrosis, hemorrhage, necrosis, degeneration and foreign debris. Histopathological evaluation revealed no significant indications of local disturbances in the physiological tissue healing processes with respect to additional pulling treatment in comparison to histological data as seen in Odermatt et al. [19]. Primarily, the tissue reaction was characterized by the presence of polynuclear giant cells as well as mononuclear cells (macrophages, lymphocytes, plasma cells). The suture fiber appeared intact at the time point of 21 postoperative days displaying signs of a beginning slight phagocytosis (Fig. 5).

Table 2. Tissue mean temperature profiles and the temperature range for the simple interrupted vs. the continuous suture technique at different stages

Situs in function of time	Simple interrupted technique		Continuous suture technique	
	T mean [ºC]	T range [ºC]	T mean [ºC]	T range [ºC]
Operation day				
rectal*		38.1 – 38.8		37.2 – 39.0
midline abdominal skin* untreated (shaved)		34.8 – 36.7		33.0 – 36.0
linea alba* (native)		35.1 – 36.9		33.2 – 36.5
natural fascia		35.7		33.6
Intestines		34.8 – 36.9		31.9 – 36.1
sutured fascia without tension**	**36.0 ± 0.7**	35.2 – 36.6	**33.3 ±0.5**	33.0 – 33.9
complete sutured fascia with 4 N tension**	**34.0 ±0.1**	34.0 – 34.2	**33.2 ±0.8**	32.3 – 33.7
single tension in pos.3		34.5***		n.a.
single tension in pos.2		34.1***		
single tension in pos. 1		33.8***		
single tension in pos. 0	34.1	33.9***		n.a.
single tension in pos. I		33.6***		
single tension in pos. II		35.5***		
single tension in pos. III		33.4***		n.a.
sutured fascia tension released**	**35.2 ±0.4**	34.8 – 35.6	**34.0 ±0.5**	33.6 – 34.3
rectal*		37.2 – 37.8		36.5 – 38.2
abdominal skin* closed		34.1 – 36.0		33.7 – 34.2
rectal*		36.3 – 37.0		35.8 – 37.6
7 days post op				
abdominal skin* wound		36.6 – 38.1		37.4 – 37.6
linea alba* through skin		37.5 – 39.1		39.0 – 39.2
rectal*		39.0 – 39.4		39.3 – 39.5
14 days post op				
abdominal skin* wound		39.6 – 40.0		38.1 – 40.0
linea alba* through skin		39.5 – 40.2		39.1 – 40.0
rectal*		38.8 – 39.5		38.8 – 39.2
21 days post op				
abdominal skin* wound		38.1 – 39.1		36.3 – 38.2
linea alba* through skin		38.3 – 38.7		38.3 – 38.6
linea alba after skin incision		36.2 – 36.5		34.0 – 37.0

**No statistical significant differences for the rectal, the abdominal skin and the linea alba temperatures*

***No statistical significant differences for the continuous suture group but statistical significant differences of simple vs. simple sutures under tension and simple sutures under tension vs. simple sutures with released tension (t-test P= 0,01).*

****only single temperature measurements not to stress the suture line*

n.a. Not applicable because the single stress application on the continuous suture in the positions III, 0 and 1 had to be dispensed because the fascia would have been distorted asymmetrically leading to not uniformly adapted tissue

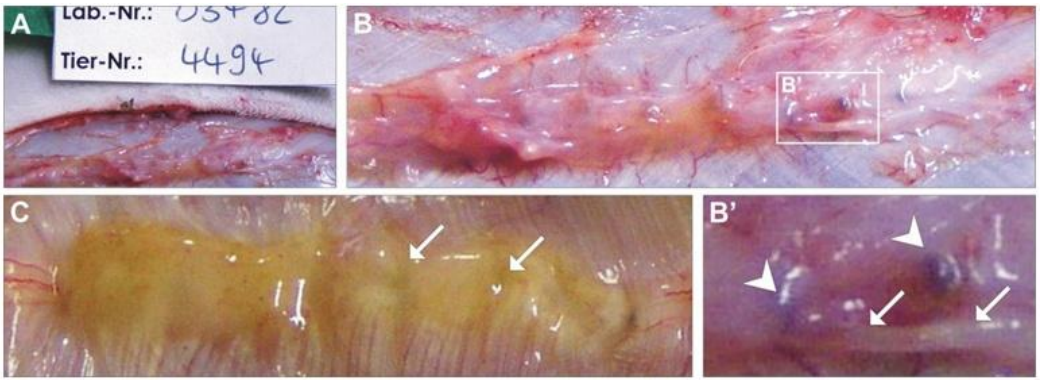

Fig. 3. Macroscopical overview of the simple interrupted technique (A) Subcutaneous situs, (B and B´) with knots (➤) and thread ends (→), (C) Intraabdominal situs with visible stitch channels (→)

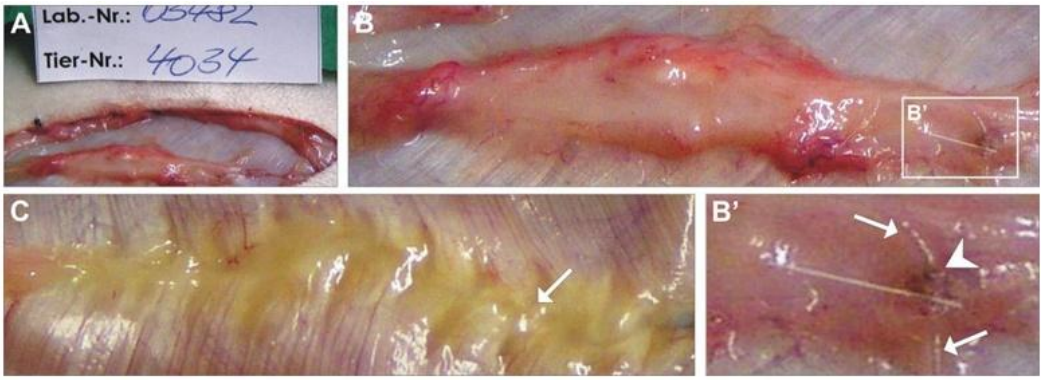

Fig. 4. Macroscopical overview of the continuous suture technique (A and B) Subcutaneous situs, (B´) with violet suture knot (➤) and transparent suture ends (→), (C) Intraabdominal situs with thread ends (→)

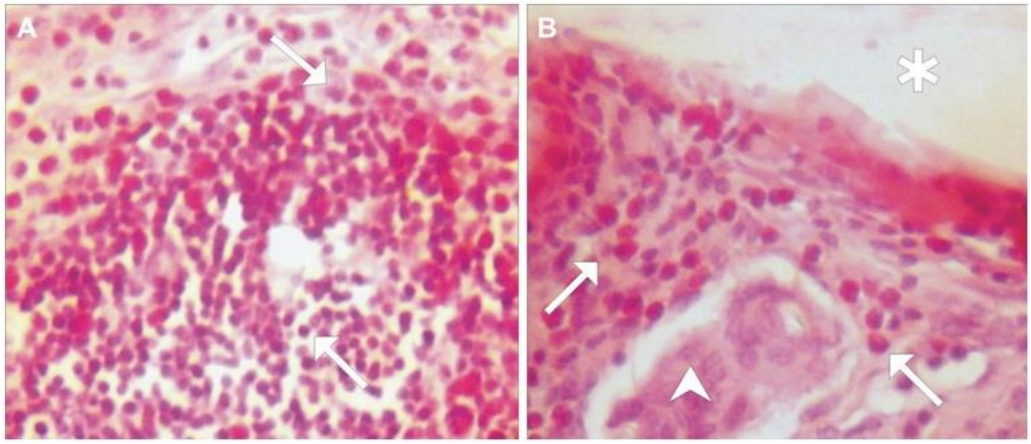

Fig. 5. Exemplary histology of a simple interrupted suture after 21 postoperative days (A and B) mild to moderate fibroplasia of various cell types being moderately rich of cells and vessels, mild to moderate infiltration of inflammation cells (→) partially having a granulomatous character adjacent to the suture material (∗) (B) multinucleated giant cells (➤) adjacent to suture material (∗) displaying phagocytosis of the suture material

4. DISCUSSION

Topological thermography of body parts is an accepted contactless and painless temperature measurement giving sufficient feedback of differences in blood flow and confirming indirectly pathological effects such as inflammation of the examined tissue, e.g. in burn wounds [20]. Those temperature differences occur during the wound healing process for sutured skin closure [21-23], abdominal fascia closure [24] and are good parameters for following up wound healing processes [25,26].

Not surprisingly, the body temperature of the rabbits decreased significantly during the surgical procedure. Although the simple interrupted suture group displayed higher thermographic results when compared to the continuous suture group, the continuous suture group seemed to be better vascularized after 7 postoperative days when compared to the simple interrupted method. After 14 and 21 postoperative days, both groups had similar temperature profiles which are in agreement with other studies [23]. The higher thermographic values of the simple interrupted suture group during surgery may be explained with the areas in between the single knots being untouched by the suturing process and tension stress. This argument is in line with Tauber et al. [24].

Historically simple interrupted suture closure layer–by-layer was used [27-29] before the 4:1 big bite continuous suture technique of Israelsson [30] was established for closing midline abdominal incisions. Nowadays, a continuous small bite suture technique is favored [31,32] in order to achieve an even distribution of tension across the entire length of the sutured incision, resulting in less strangulation of the tissue while simple interrupted sutures might hamper blood supply because of their local existing tension. Here, we compare the simple interrupted vs. a continuous suture technique with large bites to better understand the physiological effects of the wound healing of the abdominal fascia in rabbits.

We are aware of the fact that highly precise temperature measurements in open abdomen following additional surgical procedures in small animals are critical due to local evaporation leading to cooling effects. Therefore, we compared only the temperature differences in the simple interrupted vs. the simple interrupted with tension vs. the simple interrupted with released tension in itself (group 1) and vice versa for the continuous sutures (group 2) and are convinced that the experimental and analytical evaluation performed gives a realistic trend of the fasciae vascularization behavior. The simple interrupted sutures displayed a pronounced repetitive warm to cold temperature pattern in the sutured fascia reacting more sensitively to the strain than the continuous sutures which spread the tension much better and more even. This is in excellent agreement with the standard surgery recommendation of the European Hernia Society to perform a continuous suturing technique using a slowly absorbable monofilament suture in a single layer closure technique without separate suturing of the peritoneum with the small bites technique and with a suture to wound length ratio of at least 4:1 [33]. Following studies should address the comparison of a large bites vs. small bites continuous suture technique. However, this study is to be performed in larger animals in order to allow sufficient comparisons to human anatomy before a clinical study in human beings can be executed.

5. CONCLUSION

Thermographic analysis of the two compared suture techniques favored the continuous suture technique for the closure of abdominal fascia because of the better vascularization and wound healing effects being related to a more even distribution of tension across the entire length of the sutured fascia.

CONSENT

It is not applicable.

ETHICAL APPROVAL

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

COMPETING INTERESTS

C. Freytag is an independent veterinary surgeon running a GLP animal laboratory. E.K. Odermatt and B. Blender are employees of Aesculap AG, Tuttlingen which funded this research. The authors have no conflicts of interest otherwise.

REFERENCES

1. Ring EFJ. The historical development of temperature measurement in medicine. Infrared Physics & Technology. 2007;49: 297–301.
2. Hardy JD. The radiation of heat from the human body, I–IV. Journal of Clinical Investigation. 1934;13:593–620,817–883.
3. Lahiri BB, Bagavathiappan S, Jayakumar T, Philip J. Medical applications of infrared thermography: A review. Infrared Physics & Technology. 2012;55:221-235.
4. Bagavathiappan S, Philip J, Jayakumar T, Raj B, Rao PNS, Varalakshmi M, Mohan V. Correlation between plantar foot temperature and diabetic neuropathy by using an infrared thermal imaging technique. Journal of Diabetes Science and Technology. 2010;4:1386–1392.
5. Bharara M, Cobb JE, Claremont DJ. Thermography and thermometry in the assessment of diabetic neuropathic foot: A case for furthering the role of thermal techniques. International Journal of Lower Extremity Wounds. 2006;5:250–260.
6. Bagavathiappan S, Saravanan T, Philip J, Jayakumar T, Raj B, Karunanithi R, Panicker T, Korath MP, Jagadeesan K. Infrared thermal imaging for detection of peripheral vascular disorders. Journal of Medical Physics. 2009;34:43–47.
7. Kosus N, Kosus A, Duran M, Simavli S, Turhan N. Comparison of standard mammography with digital mammography and digital infrared thermal imaging for breast cancer screening. Journal of the Turkish-German Gynecological Association. 2010;11:152–157.
8. Wishart GC, Campisi M, Boswell M, Chapman D, Shackleton V, Iddles S, Hallett A, Britton PD. The accuracy of digital infrared imaging for breast cancer detection in women undergoing breast biopsy. European Journal of Surgical Oncology. 2010;36:535–540.
9. Mansfield CM, Farrell C, Asbell SO. The use of thermography in the detection of metastatic liver disease. Radiology. 1970;95:696–698.
10. Bitar D, Goubar A, Desenclos JC. International travels and fever screening during epidemics: A literature review on the effectiveness and potential use of non-contact infrared thermometers. Eurosurveillance. 2009;14:1–5.
11. Shevelev IA. Functional imaging of the brain by infrared radiation (Thermo-encephaloscopy). Progress in Neuro-biology. 1998;56:269–305.
12. Cherkas LF, Carter L, Spector TD, Howell KJ, Black CM, MacGregor AJ. Use of thermographic criteria to identify Raynaud's phenomenon in a population setting. Journal of Rheumatology. 2003;30:720–722.
13. Brooks JP, Perry WB, Putnam AT, Karulf RE. Thermal imaging in the detection of bowel ischemia. Diseases of the Colon and Rectum. 2000;43:1319–1321.
14. Costello JT, McInerney CD, Bleakley CM, Selfe J, Donnelly AE. The use of thermal imaging in assessing skin temperature following cryotherapy: A review. Journal of Thermal Biology. 2012;37:103–110.
15. Mason BR, Graff AJ, Pegg SP. Colour thermography in the diagnosis of the depth of burn injury. Burns. 1981;7:197–202.
16. Cole RP, Jones SG, Shakespeare PG. Thermographic assessment of hand burns. Burns. 1990;16:60–63.
17. Fernandez LG. Abdominal closure technique. Medscape; 2015. Available:http://emedicine.medscape.com/article/1961789-technique
18. Seiler CM, Bruckner T, Diener MK, Papyan A, Golcher H, Seidlmayer C, Franck A, Kieser M, Büchler MW, Knaebel HP. Interrupted or continuous slowly absorbable sutures for closure of primary elective midline abdominal incisions: A multicenter randomized trial (INSECT:ISRCTN24023541). Annals of Surgery. 2009;249(4):576-582. DOI: 10.1097/SLA.0b013e31819ec6c8
19. Odermatt EK, Funk L, Bargon R, Martin DP, Rizik S, Williams SF. MonoMax suture: A new long-term absorbable monofilament suture made from Poly-4-Hydroxybutyrate. Internat. J. Polymer Science. 2012;12. Article ID: 216137. Available:http://dx.doi.org/10.1155/2012/216137
20. Renkielska A, Nowakowski A, Kaczmarek M, Dobke MK, Grudezinski J, Karmolinski A, Stojek W. Static thermography revisited – An adjunct method for determining the depth of the burn injury. Burns. 2005;31:768-775. DOI: 10.1016/j.burns.2005.04.006.
21. Goldie I, Brunius U, Nilsson K. Early reactions in skin incisions in the rat. Acta Chir Scand. 1972;138:465-470.

22. Fogdestam I, Taagehoj Jensen F, Krister Nilsson S. Delayed primary closure. Blood-flow in healing rat skin incisions. Scand J Plast Reconstr Surg. 1981;15:81-85.
23. Sedlarik KM, Endres U, Ungrova A. Telethermic studies of the wound suture in animal experiments. Unfallchirurgie. 1986;12(5):234–236.
24. Tauber R, Seidel W, Gössel K, Michel KJ. Thermographical studies on the healing process in different fascia sutures. Brun´s Beitr. Klin. Chir. 1972;219(7):667–673.
25. Horzic M, Bunoza D, Maric K. Contact thermography in a study of primary healing of surgical wounds. Ostomy Wound Manage. 1996;42(1):36-44.
26. Horzic M, Bunoza D, Maric K. Three-dimensional observation of wound temperature in primary healing. Ostomy Wound Manage. 1996;42(8):38-47.
27. Ceydeli A, Rucinski J, Wise L. Finding the best abdominal closure: An evidence-based review of the literature. Curr Surg. 2005;62:220–225.
28. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: A meta-analysis. Ann Surg. 2000;231(3):436-442.
29. Rucinski J, Margolis M, Panagopoulos G, Wise L. Closure of the abdominal midline fascia: Meta-analysis delineates the optimal technique. Am Surg. 2001;67(5): 421-426.
30. Israelsson LA, Wimo A. Cost minimisation analysis of change in closure technique of midline incisions. Eur J Surg. 2000;166(8):642-646.
31. Millbourn D, Cengiz Y, Israelsson LA. Effect of stitch length on wound complications after closure of midline incisions: A randomized controlled trial. Arch Surg. 2009;144:1056-1059.
32. Deerenberg EB, Harlaar JJ, Steyerberg EW, Lont HE, van Doorn HC, Heisterkamp J, Wijnhoven BP, Schouten WR, Cense HA, Stockmann HB, Berends FJ, Dijkhuizen FP, Dwarkasing RS, Jairam AP, van Ramshorst GH, Kleinrensink GJ, Jeekel J, Lange JF. Small bites versus large bites for closure of abdominal midline incisions (STITCH): A double-blind, multicentre, randomised controlled trial. Lancet. 2015;386(10000):1254-60.
DOI: 10.1016/S0140-6736(15)60459-7
Epub 2015 Jul 15.
33. Muysoms FE, Antoniou SA, Bury K, Campanelli G, Conze J, Cuccurullo D, de Beaux AC, Deerenberg EB, East B, Fortelny RH, Gillion JF, Henriksen NA, Israelsson L, Jairam A, Jänes A, Jeekel J, López-Cano M, Miserez M, Morales-Conde S, Sanders DL, Simons MP, Śmietański M, Venclauskas L, Berrevoet F, European Hernia Society. European Hernia Society guidelines on the closure of abdominal wall incisions. Hernia. 2015;19(1):1-24.
DOI: 10.1007/s10029-014-1342-5
Epub 2015 Jan 25.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/21068