

Review

Laser Doppler Flowmetry in the Diagnosis of Intestinal Ischemia Severity

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Abstract: This systematic review evaluates the recent advancements over the past decade in the application of laser Doppler flowmetry (LDF) for measuring microcirculation and predicting outcomes in intestinal ischemia. A comprehensive analysis of experimental and clinical studies highlights the potential of LDF as a sensitive tool for assessing tissue viability and delineating ischemic boundaries. While numerous investigations demonstrate its promising diagnostic utility, significant variability in results and the lack of standardized thresholds limit widespread clinical adoption. The review emphasizes the need for further large-scale, multicenter studies to establish standardized parameter cutoff values and to optimize the integration of LDF with complementary imaging modalities. Overall, LDF remains a promising technique for enhancing the diagnosis and management of intestinal ischemia, contingent upon future validation and methodological standardization.

Keywords: Laser Doppler flowmetry, intestinal ischemia, microcirculation assessment, tissue viability, diagnostic imaging, ischemia diagnosis, perfusion measurement.

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Introduction

The method for assessing microcirculatory blood flow using laser Doppler flowmetry (LDF) has been known for quite some time. One key publication describing its basic principles is the work by Bonner RF and Nossal R (1990) [1]. LDF relies on the Doppler effect: a laser beam, upon striking living tissue, reflects from moving erythrocytes, with the frequency shift of the reflected signal proportional to blood flow velocity. This allows for non-invasive assessment of volumetric blood flow velocity and the overall state of the microcirculatory network. In various modifications, the equipment simultaneously analyzes study and control areas, conducts tests with changes in regional blood flow, and uses methods for analyzing the LDF signal spectrum in addition to basic assessment parameters. These approaches provide data on perfusion magnitude, blood flow amplitude and frequency, and assess the functional reserve and reactivity of microvessels. LDF can be performed with devices using contact or invasive sensors or in a non-contact manner.

LDF has been applied to assess regional blood flow in the extremities for conditions such as obliterating vascular diseases, diabetes mellitus, neurological diseases, burn medicine, and others. The method is widely used in pharmacological practice to evaluate changes in microcirculatory blood flow – including invasive assessments – in studies of various drug effects.

Significant interest exists in applying LDF in abdominal surgery for intraoperative assessment of intestinal blood flow, particularly in cases of ischemia and determination of resection boundaries.

Changes in microcirculatory blood flow in certain areas serve as a valuable prognostic factor, enabling determination of tissue viability and prediction of future progression. However, existing reviews do not offer a comprehensive modern assessment of LDF's development in intestinal ischemia, nor do they compare it with other methods of assessing tissue perfusion. Some reviews address LDF application in general without focusing on this specific issue.

Objective. To systematize literature data on the application of laser Doppler flowmetry (LDF) in assessing intestinal ischemia, provide a comprehensive evaluation of its use in modern experimental and clinical medicine, and identify key achievements from its implementation.

Material and Methods

We conducted a comprehensive search of more than 170 million scientific articles in available databases (PubMed, Embase, Cochrane, Scopus, Web of Science), following PRISMA criteria for a systematic review on LDF application for diagnosis and prognosis in intestinal ischemia. The search strategy focused on studying fundamental principles, experimental and clinical applications, comparative studies, and assessment of prognostic results of LDF in intestinal ischemia, including decision-making for surgical interventions. To implement our search strategy, we used keywords such as “laser Doppler flowmetry,” “intestinal ischemia,” “peritonitis,” “microcirculation,” and “outcome prediction,” including publications from 2014 onward in English and Russian.

The authors screened and extracted data according to the PRISMA 2020 flowchart for systematic reviews, presented in [Figure 1](#).

The inclusion criteria were formulated using the PICOS principle (Population, Intervention, Comparison, Outcomes, Study design):

- P: Surgical patients with intestinal ischemia of various etiologies or peritonitis.
- I: Laser Doppler flowmetry (LDF) or combined techniques.
- C: Standard methods or other perfusion assessment methods.
- O: Diagnosis, outcome prognosis, and establishment of tissue perfusion standards.
- S: Clinical, experimental, or animal studies.

We also assessed quality and risk of bias, with qualitative data synthesis highlighting key figures (sensitivity, specificity, perfusion standards) from major publications.

Thus, over the last 10 years (2014-2025), more than 150 works have been published in the global scientific literature on applying LDF to assess intestinal blood flow, predict ischemia, and justify resection volume. This reflects significant interest in using this technique to address pressing problems in abdominal surgery. Studies from the last decade emphasize its diagnostic significance, clinical application, and potential to improve surgical treatment outcomes.

[Figure 1](#) presents a comparison of opinions on the effectiveness of laser Doppler flowmetry for intraoperative determination of intestinal tissue ischemia severity and decision-making on resection boundaries. Up to 2024, 21 sources from those studied affirmatively answer the question about the proven clinical value of the LDF method for determining intestinal ischemia severity (289 citations total). These include numerous prospective clinical studies, animal experiments, or clinical case studies (with histological or clinical verification of results). Eight sources acknowledge the clinical value of LDF in addressing intestinal ischemia (200 citations), though evidence is limited by small sample sizes, narrative reviews, technical limitations, or lack of direct result verification. Further research and standardized threshold values are needed. One widely mentioned experimental animal study (19 citations), published in an authoritative journal, revealed high variability in LDF measurement results, limiting their reliability for determining perfusion levels in the colon during surgical intervention.

Interestingly, all high-impact articles (8 articles, Q1) from the last 10 years unequivocally support the use of LDF for diagnosing intestinal ischemia ([Figure 2](#)).

Detailed Analysis of Key Sources on LDF for Intraoperative Assessment of Intestinal Viability Over the Last 10 Years

In this section, we provide a detailed breakdown of each key source included in the expanded review, emphasizing modern data, methodology, and clinical significance. [Table 1](#) shows the distribution of reviewed publications by type of study (clinical/experimental/animals) over the last 10 years. In [Table 2](#) we summarize the distribution of LDF application in the areas of abdominal surgery, including veterinary applications.

Zacharenko *et al.* (2021) presented a significant study reproducing an experimental model of small intestine ischemia-reperfusion in rabbits. They assessed LDF parameters and laser fluorescence spectroscopy (LFS) compared with histology. The

authors showed that the greatest diagnostic value came from isolated assessment of nicotinamide adenine dinucleotide (NADH, reduced form) fluorescence difference (77.3%), with maximum sensitivity (85.7%) from combined analysis of LDF and LFS. They also confirmed a high correlation between decreased microcirculation, as measured by LDF, and the severity of ischemic changes. Critical LDF values included: below 21.8 PU, indicating necrosis; and above 21.8 PU, indicating viability. The authors concluded that the combined approach shows promise for objective intraoperative assessment of intestinal viability and requires further clinical validation. Authors also provide a review comparing their data with other sources [2, 3].

Verhaar and Geburek reported studies of horses with natural strangulation lesions, assessing LDF and spectrophotometry of the intestinal wall before and after strangulation relief, with data compared to histology of the resected segment. Segments with severe damage showed reliably lower perfusion as measured by LDF, though tissue perfusion figures exhibited high individual variability. Thus, LDF can detect severe ischemic intestinal damage but requires consideration of variability and additional factors [4-6].

Table 1. Distribution of publications by type of study over the last 10 years

Study Category	Number of publications (2014-2025)
Clinical	31
Experimental	8
On animals	12

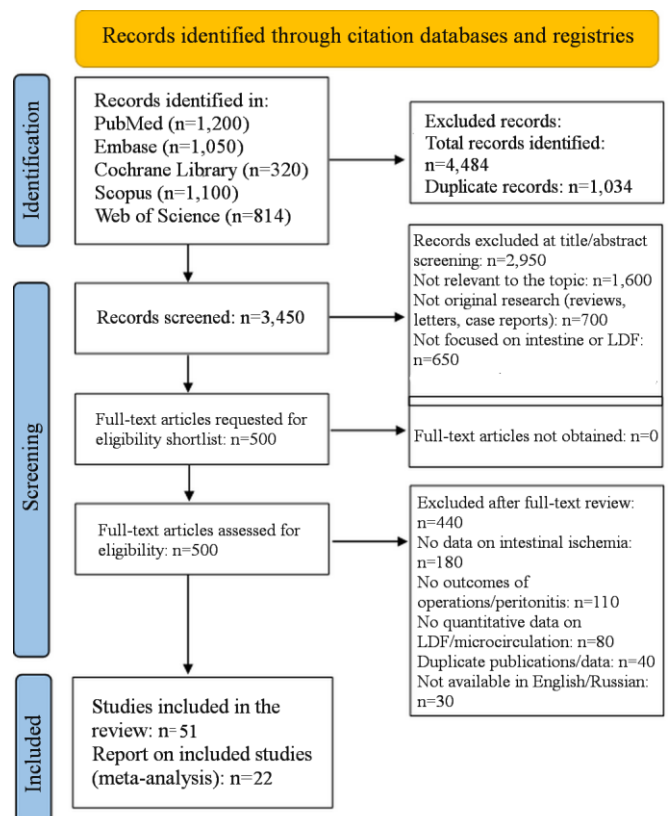


Figure 1. Flowchart of review creation methodology (PRISMA 2020).

Table 2. Distribution of the reviewed publications by main areas of LDF application in abdominal surgery

Study Topic	Clinical Studies	Animal Experiments	Perfusion Levels	Combined (LDF + Another Method)	Postoperative Outcomes
Acute Intestinal Ischemia	11	6	8	4	6
Chronic Intestinal Ischemia	5	1	3	3	2
Colonic Ischemia	7	2	5	2	4
Small Intestine Transplantation	2	None	1	1	2
Veterinary	4	3	2	2	2

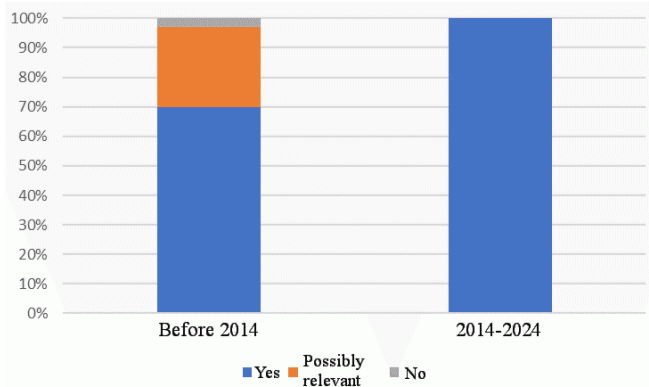


Figure 2. Level of evidence for LDF in intestinal ischemia diagnosis based on publications over the last 10 years compared to studies before 2014.

The same authors published another study describing 17 horses with colic and colon strangulation; they performed LDF and spectrophotometry, compared survivors and nonsurvivors, and correlated perfusion data with histology. After strangulation relief, tissue blood flow and oxygen saturation indicators were higher in surviving horses than in nonsurviving ones. The authors concluded that LDF can predict damage severity and survival prognosis, correlating with morphology [4].

These authors also conducted a narrative review of modern auxiliary methods (LDF, fluorescence angiography, spectrophotometry) for assessing intestinal viability in horses [7]. They concluded that LDF and fluorescence angiography are actively being introduced into veterinary and human surgery, but blinded clinical studies and standardized thresholds are lacking. In their opinion, LDF is a minimally invasive, promising method that requires standardization and further research for widespread implementation.

One more literature review on modern methods of intraoperative assessment of intestinal ischemia recommends LDF, ultrasound, and angiotonometry as highly sensitive methods for assessing intestinal microcirculation [8]. The authors recommend LDF for objective perfusion assessment but note the need for further standardization and clinical validation.

In a study by Wang *et al.* (2022) on an experimental pig model of induced intestinal ischemia (anastomosis formation, vessel ligation), LDF was evaluated as a contact method for quantitative microcirculation assessment [9]. The authors analyzed 35 datasets, showing that LDF provides high sensitivity to local perfusion changes but is limited by a small measurement area and potential mechanical influence of the sensor on blood flow. Compared with non-contact laser speckle contrast imaging (LSCI), LDF is inferior in tissue coverage and analysis speed, complicating its use for comprehensive intraoperative ischemia severity diagnosis. Nevertheless, the method demonstrates value in point monitoring of critical zones, complementing multimodal optical approaches to increase accuracy in determining resection boundaries.

Kiseleva *et al.* (2021) recognized LDF as a pioneering method for intraoperative assessment of intestinal perfusion in acute mesenteric ischemia, showing high sensitivity to ischemic damage prediction and differentiation of zones with critical blood supply [10]. Based on clinical data from 18 patients (including 9 with acute mesenteric ischemia) and an experimental phase on a pig intestine model, the authors emphasized that LDF allows quantitative determination of decreased microcirculatory flow, correlating with histological changes and helping establish viable tissue boundaries. However, the method is limited by point measurements, inability to visualize structural intestinal wall damage, and the need for combination with multimodal optical coherence tomography (OCT) for comprehensive ischemia severity diagnosis and resection volume optimization.

Timerbulatov *et al.* (2017) applied LDF using the LAKK-02 (laser analyzer of capillary blood flow) for diagnosing ischemic intestinal damage in an experimental model of intra-abdominal hypertension in 5 pigs and 7 piglets, supplemented by clinical data from 203 patients with acute surgical abdominal diseases [11]. The method revealed a sharp decrease in microcirculatory flow in the serous membrane of ischemic zones (up to 90% of normal), as well as reflex ischemia in adjacent areas, ensuring accurate determination of tissue viability and resection boundaries over 90%. LDF surpasses visual and palpatory assessment in objectivity and reproducibility, showing potential in intraoperative monitoring to minimize necrobiotic changes and improve outcomes in acute mesenteric ischemia.

In an experimental study described in a patent for invention [12], the authors proposed an innovative method for determining intestinal viability and optimal resection boundaries in strangulation intestinal obstruction using laser spectrophotometry to assess intestinal wall microcirculation in laboratory animals. The method involves measuring perfusion indicators during strangulation and after relief, followed by injection of 0.5 mL of 1% nicotinic acid solution into the mesentery of the studied segment. After 5 minutes, perfusion is reassessed and compared with healthy intestine indicators. Restoration of perfusion to healthy levels indicates segment viability, enabling objective real-time registration of microcirculation changes with high accuracy and informativeness. This approach complements laser Doppler flowmetry, increasing the reliability of intraoperative ischemia severity diagnosis and minimizing resection volume.

Regarding combined techniques (McGuinness-Abdollahi *et al.*, 2015), the authors suggested a combined LDF+PPG sensor, with clinical measurements in 30 patients at different operation stages [13]. Earlier, the same author reported results from a study using a constructed sensor for simultaneous LDF and PPG monitoring during intestinal resection in 24 patients (Abdollahi, 2015). The conclusion was that LDF and PPG record perfusion changes at critical stages of intestinal wall ischemia development, with LDF more sensitive to motion artifacts [14]. The authors concluded that such combined methods enable objective perfusion

assessment and early detection of anastomotic failure risk, showing technical feasibility and superiority over separate LDF use.

Russian authors Shevchenko and Polikov (2019) presented results from studying intestinal wall microcirculation using LDF in patients with intestinal wall necrosis [15]. They concluded that in necrosis, microcirculation is undetectable via LDF, confirming necrosis objectively and helping avoid excessive resections.

Parshin *et al.* (2020) reported data from a retrospective study of 54 patients with peritonitis, analyzing intestinal microcirculation parameters via LDF [16]. The authors found that low LDF values are associated with future complication development. Significant indicators included microcirculation percentage ($r=0.77$, $P<0.05$), standard deviation ($r=0.67$, $P<0.05$), and variation coefficient ($r=0.59$, $P<0.05$). In the main group (with complications), $PM=17.6\pm 1.55$ PU; in the comparison group, 23.37 ± 1.83 PU; reference, 32.21 ± 1.18 PU. Subsequently (Parshin and Topchiyev, 2021), these authors described a study of 48 patients measuring peritoneal microcirculation via LDF during and after surgery (via drains at 24 and 48 hours). By 24 hours postoperatively, LDF indicators (microcirculation percentage, standard deviation, and variation coefficient) significantly correlated with tertiary peritonitis development ($r=0.71$; $r=0.55$; $r=0.63$; $P<0.05$) [17]. Thus, microcirculation disorders detected by LDF can indicate recurrent peritonitis risk in the postoperative period.

In human studies, LDF assessed microcirculation in patients with chronic mesenteric ischemia (CMI) and median arcuate ligament syndrome (MALS) [18–20]. Often combined with visible light spectroscopy, LDF revealed significantly reduced mucosal microcirculatory perfusion in patients with CMI compared with controls, demonstrating high sensitivity and specificity in diagnosis. Posttreatment, measurable microcirculation improvements confirmed LDF's role in monitoring therapy effectiveness [21]. Berge *et al.* (2019), in a study of 104 patients with chronic mesenteric ischemia, used LDF and visible spectroscopy to show significant microcirculation reduction in the stomach and duodenum compared with controls [22]. Mean capillary blood oxygen saturation (SO_2): $67\pm 9\%$ in patients vs. $81\pm 4\%$ in controls ($P<0.001$). SO_2 sensitivity for ischemia diagnosis was 94%, and specificity was 72% (cutoff 78%).

Aksoy N *et al.* (2024) reported that, based on their research, LDF detects significant microcirculation changes in patients with adhesive intestinal obstruction, potentially marking future complication development [23].

Thus, LDF demonstrates high sensitivity and objectivity for intraoperative assessment of intestinal viability, especially in ischemia and resection boundary determination, which mentioned and approved in a number of other less significant papers [24–52].

It should be noted that while 52 references are included in this review, the synthesis is centered on the most methodologically sound and directly relevant studies. References 24–52, which encompass supplementary experimental, clinical, and veterinary studies, are cited to reflect the wider research landscape but are not elaborated upon individually. This selective focus is a limitation of the present review format.

Key Points

- LDF enables objective, quantitative assessment of microcirculation, essential for determining resection boundaries and avoiding complications.

- The threshold value of <50 PU is confirmed as critical for intestinal viability in multiple clinical and experimental studies.

- Combined methods (LDF+LFS, LDF+PPG) enhance diagnostic sensitivity and reliability.

- In veterinary and experimental surgery, LDF demonstrates high correlation with morphology and outcomes.

- Standardization, large-scale RCTs, and LDF integration into modern surgical protocols are necessary.

Conclusion

Current data confirm LDF's advantage over clinical criteria and its comparability with other optical methods for predicting complications and optimizing surgical tactics. For widespread implementation, standardization of threshold values, large-scale clinical studies, and integration with other technologies (LFS, spectrophotometry, PPG) are required.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Use of AI

During review preparation, AI tools were not used for data searching and processing, except for AI embedded in GOOGLE and YANDEX search engines.

References

1. Bonner RF, Nossal R. Principles of Laser-Doppler Flowmetry. In: Shepherd AP, Öberg PÅ, Eds. Laser-Doppler Blood Flowmetry. Developments in Cardiovascular Medicine. Vol. 107. Boston: Springer. 1990: 17-45. https://doi.org/10.1007/978-1-4757-2083-9_2.
2. Zacharenko AA, Belyaev MA, Trushin AA, Zaytcev DA, Kursenko RV. Bowel viability assessment during surgery (review of the literature). *Grekov's Bulletin of Surgery* 2020; (1): 82-88. <https://doi.org/10.24884/0042-4625-2020-179-1-82-88>.
3. Zacharenko AA, Belyaev MA, Trushin AA, Zaytcev DA, Kursenko RV, Sidorov VV, et al. Combined assessment of intestinal viability using laser doppler flowmetry and laser fluorescence spectroscopy. *Regional Blood Circulation and Microcirculation* 2021; 20(2): 70-76. Russian. <https://doi.org/10.24884/1682-6655-2021-20-2-70-76>.
4. Verhaar N, Reineking W, Hewicker-Trautwein M, Grages AM, Kästner SBR, Geburek F. Flowmetry and spectrophotometry can detect reduced intestinal microperfusion in nonsurvivors during equine colic surgery for large intestinal strangulation. *Am J Vet Res* 2024; 85(10): ajvr.24.05.0142. <https://doi.org/10.2460/ajvr.24.05.0142>.
5. Verhaar N, Grages AM, Sauer FJ, Geiger T, Reineking W, Hewicker-Trautwein M, et al. Measuring tissue oxygen saturation in the oral intestinal segment during equine colic surgery may aid in predicting the occurrence of postoperative ileus. *Am J Vet Res* 2024; 85(7): ajvr.23.12.0286. <https://doi.org/10.2460/ajvr.23.12.0286>.
6. Verhaar N, Grages AM, Bienert-Zeit A, Schwieder A, Reineking W, Hewicker-Trautwein M, et al. Flowmetry and spectrophotometry for the assessment of intestinal viability in horses with naturally occurring

- strangulating small intestinal lesions. *Equine Vet J* 2024; 56(6): 1138-1148. <https://doi.org/10.1111/evi.14118>.
7. Verhaar N, Geburek F. Real-time ancillary diagnostics for intraoperative assessment of intestinal viability in horses-looking for answers across species. *Vet Surg* 2025; 54(4): 648-664. <https://doi.org/10.1111/vsu.14248>.
 8. Adamenkov NA, Mamoshin AV, Dremine VV, Potapova EV, Shupletsov VV, Ivanov YV, et al. Intraoperative evaluation of the intestinal wall viability. *Journal of Clinical Practice* 2024; 15(4): 46-58. Russian. <https://doi.org/10.17816/clinpract633149>.
 9. Wang Y, Tijsaba L, Jacobs S, Saruwatari M, Ning B, Levitt M, et al. Unsupervised and quantitative intestinal ischemia detection using conditional adversarial network in multimodal optical imaging. *J Med Imaging (Bellingham)* 2022; 9(6): 064502. <https://doi.org/10.1117/1.JMI.9.6.064502>.
 10. Kiseleva E, Ryabkov M, Baleev M, Bederina E, Shilyagin P, Moiseev A, et al. Prospects of Intraoperative Multimodal OCT Application in Patients with Acute Mesenteric Ischemia. *Diagnostics (Basel)* 2021; 11(4): 705. <https://doi.org/10.3390/diagnostics11040705>.
 11. Timerbulatov VM, Timerbulatov ShV, Sagitov RB, Sultanabaev AU, Asmanov DI. Diagnostics of the intestine ischemic damages in some acute surgical diseases of abdominal cavity. *Creative Surgery and Oncology* 2017; 7(3): 12-19. Russian. <https://doi.org/10.24060/2076-3093-2017-7-3-12-19>.
 12. Sigachev PV, Tolstokorov AS, Kapralov SV, Semyachkina-Glushkovskaya OV. Method for determining viability of intestine and optimal bounds of resection of strangulated intestinal obstruction in surgical operation. Patent number: RU 2680915. Application number: 2017140168. Date of registration: November 20, 2017. 2019. <https://www.elibrary.ru/zdzurn>.
 13. McGuinness-Abdollahi Z, Thaha MA, Ramsanahie A, Ahmed S, Kyriacou PA, Phillips JP. Intraoperative monitoring of intestinal viability: Evaluation of a new combined sensor. *Annu Int Conf IEEE Eng Med Biol Soc* 2015; 2015: 5126-5129. <https://doi.org/10.1109/EMBC.2015.7319545>.
 14. McGuinness Abdollahi Z. Intra-operative optical monitoring of bowel tissue viability based on photoplethysmography and laser doppler flowmetry. Doctoral Thesis. London. 2015; 222 p. <https://openaccess.city.ac.uk/id/eprint/13684>.
 15. Shevchenko AN, Polikov HO. Instrumental Diagnostics in Patients with the Development of Necrobiotic Processes in the Intestinal Wall. *International Journal of Education and Science* 2019; 2(2). <https://doi.org/10.26697/ijes.2019.2.49>.
 16. Parshin DS, Topchiyev MA. Peritoneal Laser Doppler Flowmetry in Predicting and Diagnosing Tertiary Peritonitis. *Russian Sklifosovsky Journal "Emergency Medical Care"* 2020; 9(3): 410-416. <https://doi.org/10.23934/2223-9022-2020-9-3-410-416>.
 17. Parshin D, Topchiev M, Kupriyanov A, Aliyev M, Abdullaev A, Goryaeva O. Is it possible to predict postoperative abdominal complications by laser doppler flowmetry? *Archiv Euromedica* 2021; 11: 81-84. <https://doi.org/10.35630/2199-885X/2021/11/6.19>.
 18. Kazmi SSH, Safi N, Berge ST, Kazmi M, Sundhagen JO, Hisdal J. Laparoscopic surgery for median arcuate ligament syndrome (MALS): a prospective cohort of 52 patients. *Vasc Health Risk Manag* 2022; 18: 139-151. <https://doi.org/10.2147/vhrm.s350841>.
 19. Kazmi SSH, Safi N, Berge ST, Kazmi M, Sundhagen JO, Julien K, et al. Plasma α -Glutathione S-Transferase in Patients with Chronic Mesenteric Ischemia and Median Arcuate Ligament Syndrome. *Vasc Health Risk Manag* 2022; 18: 567-574. <https://doi.org/10.2147/vhrm.s365625>.
 20. Edwin GVG, Skraastad BKB, Hisdal J, Wisløff T, Sundhagen JO, Kazmi SSH. Assessment of Transserosal Microcirculation with Visible Light Spectroscopy and Laser Doppler Flowmetry in Patients with Median Arcuate Ligament Syndrome and Chronic Mesenteric Ischemia. *Vasc Health Risk Manag* 2025; 21: 61-69. <https://doi.org/10.2147/vhrm.s484787>.
 21. Gorbatiuk R, Bukata V, Volch I, Khrabra S, Kobylanskiy O, Stoliarenko O, et al. Laser doppler for diagnosis of changes of microcirculation in the perioperative period in patients with acute adhesive obstruction of small gut. *Proceedings of the SPIE* 2020; 11456: 114560K. <https://doi.org/10.1117/12.2569779>.
 22. Berge ST, Safi N, Medhus AW, Ånonsen K, Sundhagen JO, Hisdal J, et al. Gastroscopy assisted laser Doppler flowmetry and visible light spectroscopy in patients with chronic mesenteric ischemia. *Scand J Clin Lab Invest* 2019; 79(7): 541-549. <https://doi.org/10.1080/00365513.2019.1672084>.
 23. Aksoy N, Kaplan DS, Orkmez M, Eronat Ö. Evaluation of intestinal necrosis with laser Doppler in experimental mesenteric ischemia model. *Ulus Travma Acil Cerrahi Derg* 2024; 30(1): 1-8. <https://doi.org/10.14744/tjtes.2024.38399>.
 24. Safi N, Johannessen HO, Medhus AW, Mala T, Kazmi SSH. Laser Doppler Flowmetry and Visible Light Spectroscopy of the Gastric Tube During Minimally Invasive Esophagectomy. *Vasc Health Risk Manag* 2020; 16: 497-505. <https://doi.org/10.2147/vhrm.s269138>.
 25. Kania A, Branchi V, Braun L, Verrel F, Kalf J, Vilz TO. Indications and surgical strategy for bowel resection in mesenteric ischemia: Resection margins considering current guidelines and literature as well as the influence of new technical possibilities. *Chirurgie (Heidelb)* 2024; 95(5): 367-374. <https://doi.org/10.1007/s00104-024-02041-w>.
 26. Ryabkov MG, Peretyagin PV, Shestakova SA, Ptushko SS, Koshmanev MS, Bederina YL, et al. Diagnosis of Skin Burn-Induced Colon Circulatory Disorders Using Optical Coherence Tomography Angiography and Laser Doppler Flowmetry (Experimental Study). *Sovrem Tekhnologii Med* 2024; 16(2): 47-55. <https://doi.org/10.17691/stm2024.16.2.05>.
 27. Sheng L, Hu F, Yu H, Tao X, Jia R, Gu Y, et al. Paeoniflorin Inhibits ASK1-TF Axis by Up-Regulating SOCS3 to Alleviate Radiation Enteritis. *Front Pharmacol* 2022; 13:743708. <https://doi.org/10.3389/fphar.2022.743708>.
 28. Yu Q, Yang X, Zhang C, Zhang X, Wang C, Chen L, et al. AMPK activation by ozone therapy inhibits tissue factor-triggered intestinal ischemia and ameliorates chemotherapeutic enteritis. *FASEB J* 2020; 34(9): 13005-13021. <https://doi.org/10.1096/fj.201902717rr>.
 29. Gordeeva AE, Sharapov MG, Tikhonova IV, Chemeris NK, Fesenko EE, Novoselov VI, et al. Vascular Pathology of Ischemia/Reperfusion Injury of Rat Small Intestine. *Cells Tissues Organs* 2017; 203(6): 353-364. <https://doi.org/10.1159/000455830>.
 30. Mester A, Magyar Z, Sogor V, Tanczos B, Stark Y, Cherniavsky K, et al. Intestinal ischemia-reperfusion leads to early systemic microhemorrhagic and multiorgan microcirculatory alterations in the rat. *Clin Hemorheol Microcirc* 2018; 68(1): 35-44. <https://doi.org/10.3233/ch-170278>.
 31. Schucht JE, Matheson PJ, Harbrecht BG, Bond L, Jones S, Alkhatieb KJM, et al. Plasma resuscitation with adjunctive peritoneal resuscitation reduces ischemic intestinal injury following hemorrhagic shock. *J Trauma Acute Care Surg* 2020; 89(4): 649-657. <https://doi.org/10.1097/ta.0000000000002847>.
 32. Yalcin D, Saçak B, Yalcin M, Yildirim A, Karademir B, Ercan F, et al. Intraluminal fluid infusion in a rat jejunum ischemia/reperfusion model is associated with improved tissue perfusion and less mucosal damage. *J Plast Reconstr Aesthet Surg* 2020; 73(3): 590-597. <https://doi.org/10.1016/j.bjps.2019.09.019>.
 33. Toropova YG, Pechnikova NA, Zelinskaya IA, Zhuravsky SG, Korniyushin OV, Gonchar AI, et al. Nicotinamide riboside has protective effects in a rat model of mesenteric ischaemia-reperfusion. *Int J Exp Pathol* 2018; 99(6): 304-311. <https://doi.org/10.1111/iep.12302>.
 34. Procházka V, Jurčíková J, Vítková K, Pavliska L, Porubová L, Lassák O, et al. The Role of miR-126 in Critical Limb Ischemia Treatment Using Adipose-Derived Stem Cell Therapeutic Factor Concentrate and Extracellular Matrix Microparticles. *Med Sci Monit* 2018; 24: 511-522. <https://doi.org/10.12659/msm.905442>.

35. Lipnitsky EM, Leontyev AV, Nikolaeva EA. Diagnosis of microcirculation features in intestinal anastomosis to prevent its failure. *Khirurgiia (Mosk)* 2019; (2): 78-81. Russian. <https://doi.org/10.17116/hirurgia201902178>.
36. Kaska M, Blazej S, Turek Z, Ryska A, Jegorov B, Radochova V, et al. The effect of three different surgical techniques for colon anastomosis on regional postoperative microperfusion: Laser Doppler Flowmetry study in pigs. *Clin Hemorheol Microcirc* 2018; 68(1): 61-70. <https://doi.org/10.3233/CH-170297>.
37. Rutegård M, Hassmén N, Hemmingsson O, Haapamäki MM, Matthiessen P, Rutegård J. Anterior Resection for Rectal Cancer and Visceral Blood Flow: An Explorative Study. *Scand J Surg* 2016; 105(2): 78-83. <https://doi.org/10.1177/1457496915593692>.
38. Kojima S, Sakamoto T, Nagai Y, Matsui Y, Nambu K, Masamune K. Laser Speckle Contrast Imaging for Intraoperative Quantitative Assessment of Intestinal Blood Perfusion During Colorectal Surgery: A Prospective Pilot Study. *Surg Innov* 2019; 26(3): 293-301. <https://doi.org/10.1177/1553350618823426>.
39. Rønn JH, Nerup N, Strandby RB, Svendsen MBS, Ambrus R, Svendsen LB, et al. Laser speckle contrast imaging and quantitative fluorescence angiography for perfusion assessment. *Langenbecks Arch Surg* 2019; 404(4): 505-515. <https://doi.org/10.1007/s00423-019-01789-8>.
40. Strandby RB, Osterkamp JTF, Ambrus R, Henriksen A, Goetze JP, Secher NH, et al. Mesenteric traction syndrome in pigs: A single-blinded, randomized controlled trial. *Animal Model Exp Med* 2021; 4(2): 162-168. <https://doi.org/10.1002/ame2.12160>.
41. Ambrus R, Strandby RB, Svendsen LB, Achiam MP, Steffensen JF, Søndergaard Svendsen MB. Laser Speckle Contrast Imaging for Monitoring Changes in Microvascular Blood Flow. *Eur Surg Res* 2016; 56(3-4): 87-96. <https://doi.org/10.1159/000442790>.
42. Back E, Brännström F, Svensson J, Rutegård J, Matthiessen P, Haapamäki MM, et al. Mucosal blood flow in the remaining rectal stump is more affected by total than partial mesorectal excision in patients undergoing anterior resection: a key to understanding differing rates of anastomotic leakage? *Langenbecks Arch Surg* 2021; 406(6): 1971-1977. <https://doi.org/10.1007/s00423-021-02182-0>.
43. Yagi M, Morishita K, Ueno A, Nakamura H, Akabori H, Senda A, et al. Electrical stimulation of the vagus nerve improves intestinal blood flow after trauma and hemorrhagic shock. *Surgery* 2020; 167(3): 638-645. <https://doi.org/10.1016/j.surg.2019.09.024>.
44. Jensen DM, Ohning GV, Kovacs TO, Ghassemi KA, Jutabha R, Dulai GS, et al. Doppler endoscopic probe as a guide to risk stratification and definitive hemostasis of peptic ulcer bleeding. *Gastrointest Endosc* 2016; 83(1): 129-136. <https://doi.org/10.1016/j.gie.2015.07.012>.
45. Kaneko T, Funahashi K, Ushigome M, Kagami S, Yoshida K, Koda T, et al. Noninvasive assessment of bowel blood perfusion using intraoperative laser speckle flowgraphy. *Langenbecks Arch Surg* 2020; 405(6): 817-826. <https://doi.org/10.1007/s00423-020-01933-9>.
46. Urboniene A, Palepsaitis A, Uktveris R, Barauskas V. Doppler flowmetry of the superior mesenteric artery and portal vein: impact for the early prediction of necrotizing enterocolitis in neonates. *Pediatr Surg Int* 2015; 31(11): 1061-1066. <https://doi.org/10.1007/s00383-015-3792-y>.
47. Tekola B, Smith E, Mann J, Patrie J, Moskaluk C, Caldwell S. Antral mucosal perfusion is not increased in GAVE. *Postgrad Med* 2017; 129(3): 312-317. <https://doi.org/10.1080/00325481.2017.1301191>.
48. Hopster K, Neudeck S, Wittenberg-Voges L, Kästner SB. The relationship between intestinal and oral mucosa microcirculation in anaesthetized horses. *Vet Anaesth Analg* 2018; 45(1): 78-81. <https://doi.org/10.1016/j.vaa.2017.07.005>.
49. Pajk W, Stadlbauer KH, Kleinsasser A, Kotzinger O, Ulmer H, Hasibeder W, et al. The impact of endotoxin on jejunal tissue oxygenation. *Microcirculation* 2017; 24(6). <https://doi.org/10.1111/micc.12379>.
50. Birgin E, Yang C, Brunner A, Hetjens S, Rahbari M, Bork U, et al. A postresection perfusion deficit in the right colon is an independent predictor of perioperative outcome after major hepatectomy. *J Hepatobiliary Pancreat Sci* 2022; 29(7): 785-797. <https://doi.org/10.1002/jhbp.1089>.
51. Brunauer A, Koköfer A, Bataar O, Gradwohl-Matis I, Dankl D, Bakker J, et al. Changes in peripheral perfusion relate to visceral organ perfusion in early septic shock: A pilot study. *J Crit Care* 2016; 35: 105-109. <https://doi.org/10.1016/j.jcrc.2016.05.007>.
52. Trushin AA, Kursenko RV, Vervekin IV, Ten OA, Belyaev MA, Zakharenko AA. Microcirculation and oxydative metabolism measured by laser doppler flowmetry and laser fluorescent spectroscopy and its role in bowel anastomosis leakage assessment. *Medline.ru* 2024; 25(1): 383-421. <https://www.elibrary.ru/ogdxzw>.

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