Mini Review
Volume 5:1, 2021

Journal of Morphology and Anatomy

ISSN: 2684-4265

Open Access

Scanning Electron Microscopy of Vascular Corrosion Casts in Biological and Biomedical Research

Alois Lametschwandtner* and Bernd Minnich

Department of Biosciences, University of Salzburg, Salzburg, Austria

Abstract

The cardiovascular system is the first system to develop and to function. It supplies tissues and organs with oxygen, nutrients, hormones, immune competent cells and others and deliberates them from waste products and metabolic heat. Many attempts were made to gain insights into its three-dimensional structure by injecting air, liquids, waxes or hardening substances.

Keywords

Hormones • Arteries • Veins • Blood vascular system • Capillaries

About the Study

A real breakthrough was gained some 50 years ago [1-5]. Casting media became available which replicated the entire blood vascular system from the arteries through capillaries to the veins and resulting vascular casts were robust enough to allow their examination under the scanning electron microscope [6-13]. These resins resist corrosive agents used to remove soft and hard tissues and replicate and preserve minute details of the luminal (endothelial) surface of blood vessels which in turn enable to distinguish between arterial and venous vessels by the characteristic shapes and orientations of endothelial cell nuclei imprints presented at the casted surfaces [14-20] (Figure 1). For more details, see the references [21-29].

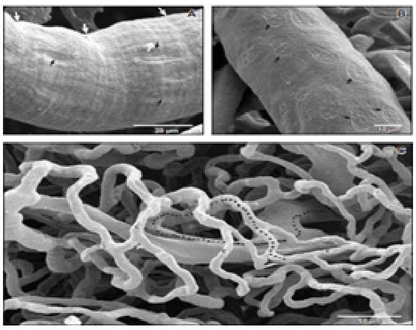

Figure 1. Characteristic endothelial cell nuclei imprint patterns displayed on the surface of vascular casts. Scanning electron micrographs: A.Arteriole with longish imprints of endothelial cell nuclei orientated parallel to the longitudinal axis of the artery (thin arrows). Thick arrows point at imprints of single or groups of vascular smooth muscle cells (sphincters),B.Vein with shallow ovoid to roundish imprints of endothelial cell nuclei (arrows), C.Capillaries (c) building a three-dimensional meshwork. Dotted line indicates a capillary-venous transition route.

Address for Correspondence: *Dr. Alois Lametschwandtner, Department of Biosciences, University of Salzburg, Salzburg, Austria, Tel: +4366280445607; E-mail: Alois.Lametschwandtner@sbg.ac.at*

Received January 7, 2021; **Accepted** January 21, 2021; **Published** January 28, 2021

Literature Review

Modern casting media are cuttable into slices by razor blades can be frozen in distilled water and thereafter sectioned by a mini wheel saw or they can be micro-dissected using fine tipped insect pins to expose and re-examine individual vascular territories layer by layer in consecutive SEM sessions [12,30].

For studies of vascular patterns, qualitative data is often enough. Quantitative data on vessel diameters, inter-branching and inter-vascular distances as well as branching angles are needed for hemodynamic calculations of interesting vascular territories. This data can be gained by 3D-morphometry of stereo paired scanning electron micrographs [31-35]. Data gained allows insights into hemodynamic properties of individual vascular segments like wall shear stress [36]. Moreover, these data enable to test real vascular networks for optimality principles [37,39].

In biological research blood vascular systems of individual organs or tissues can be studied on a phylogenetic or an evolutionary scale [40-46]. In these studies, similarities/dissimilarities in origins, courses, branching patterns and areas of supply or drainage of individual vessels are in focus aiming to understand how the blood vascular system maintains blood supply under altered needs according to functional changes of individual tissues and organs. Beyond this, SEM of Vascular Corrosion Castings (VCCs) elegantly allows to locate flow regulating structures, such as muscular sphincters, flow dividers, intimal cushions, and venous valves [47-51] (Figure 2). Furthermore, one can also study Arterio-Arterial Anastomoses (AAAs), Arterio-Venous Anastomoses (AVAs), and Veno-Venous Anastomoses (VVAs).

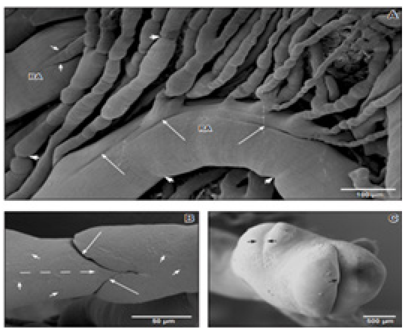

Figure 2. A.Renal Arteries (RA) giving off numerous afferent glomerular arterioles. Note imprints of an intra-arterial cushion (short thin arrows), flow dividers (long thin arrows), and vascular smooth muscle cells (sphincters) (short thick arrows), B.Venous valve (long thin arrows). Short thin arrows point at imprints of endothelial cell nuclei. Dashed line indicates the direction of blood flow, C.Two venous valves (arrows) where the retrograde flow of resin was stopped by the valves.

SEM of VCCs is the method of choice in the study of venous portal circulations, where postcapillary venules form portal veins, course over shorter or longer distances, and then capillarize again. Such portal circulations studied in vertebrates are the hypothalamo-hypophysial portal system in the brain, the hepatic portal vein system, the renal portal vein system and the pancreas insulo-acinar portal system [21,22,52-59].

The embryonal and early larval development of the cardiovascular system is excellently visualized by confocal micro-angiography. This technique is well suited for optically clear (transparent) thin animals but fail in opaque and thick objects. Here SEM of VCCs can be applied. Our group focusses upon spatio-temporal aspects of growth and regression of blood vessels in the Xenopus laevis model organism. Xenopus is an anuran amphibian and undergoes drastic changes in basically every organ/tissue during metamorphosis [60]. Most obvious is the loss of larval-specific organs, like the gills and tail. These organs are highly vascularized in early stages of metamorphosis where the growth of blood vessels dominates [61,62]. At the height of metamorphosis (climax), gills and tail are resorbed and regression of a highly differentiated, complex vascular system can be studied [63,64]. But also the microvascular anatomies of chick embryos, mouse embryos, rat embryos and of isolated human fetal organs have been successfully studied by this technique [65-72]. Angiogenesis research is another field of application of SEM of VCCs. Here blood vessels that undergo sprouting and/or non-sprouting angiogenesis can be identified and localized (Figure 3).

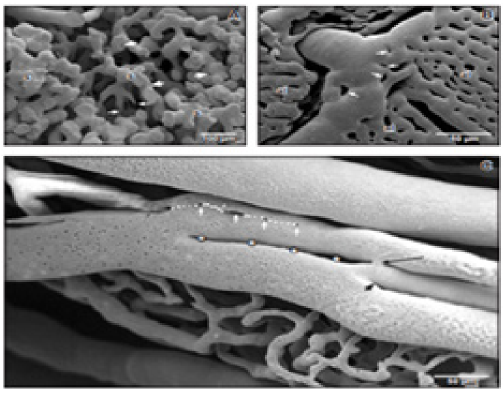

Figure 3. Signs of sprouting and non-sprouting angiogenesis (intussusceptive microvascular growth) as displayed by vascular corrosion casts:A.Sprouting angiogenesis. Thin arrows point at vascular sprouts, thick arrows at sites of intussusceptive angiogenesis. s sinusoids, B.Non-sprouting angiogenesis. Intussusceptive branch remodeling (arrows). al alveolus, C.Non-sprouting angiogenesis. Intussusceptive branch remodeling (thin short arrows) Dotted line indicates the possible shift of the future origin of the vessel towards the right. Short thick arrow points at a site where intussusceptive pruning takes place. Note anastomosis (thin long arrow) between two vessels. Asterisks mark the site of a tissue lamella separating adjacent vessels.

In corrosion casts, vascular sprouts impose as blind ending tapering vessels preferentially occurring at capillary and postcapillary venular sites. Their identification in vascular casts should always be related to the state of the tissue under observation (healthy vs. diseased; growing vs. fully differentiated vs. involuting). Non-sprouting angiogenesis (Intussusceptive Microvascular Growth, IMG) and its facets Intussusceptive Arborization (IA), Intussusceptive Branch Remodeling (IBR), and Intussusceptive Pruning (IP) can be identified. Signs of non-sprouting angiogenesis impose in vascular casts as shallow to deep, round, oval or longish impressions or as holes or slits of different sizes and shapes [73-80].

In biomedical research SEM of VCCs is applied in atherosclerosis research, diabetes research, nephrology research, ophthalmologic research, tissue engineering research and tumor research [81-101]. Studies on tumor vascular casts show that the normal hierarchy of the blood vascular system can be highly disturbed and vascular patterns can extremely differ. In tumors, the positive identification of casted structures such as blood vessels is sometimes difficult since casts of tumor vascular beds differ greatly in their appearance from casted normal blood vessels. Within short distances they change their diameters, kink, out pouch, constrict, or end abruptly. In areas of vascular mimicry, imprints of tumor cells can be found on their surfaces and in necrotic areas casted structures are found that resemble extravasations. A clear differentiation of casted vascular structures from artifacts is difficult and needs supplemental techniques.

Like other techniques, vascular corrosion casting is also prone to artifacts. Incompletely casted blood vessels impose as blindly ending vessels with rounded tips. They can be positively differentiated from broken vessels, which show straight, sharp endings, and also from sprouting vessels, which impose with gradually tapering endings. In some cases, “plastic strips” are found around vascular casts. According to their shape and rather annular structure, they are considered to represent plastified vascular smooth muscle cells or pericytes [102-107].

Discussion and Conclusion

Vascular corrosion casts are increasingly investigated by micro-computer tomography (μ-CT). To gain spatial resolution comparable to that of the conventional SEM, only very small specimens can be studied, a disadvantage if vascular routes connecting areas far apart each other are in the focus of interest.

References

1. Hyrtl, Joseph. “The Corrosion Anatomy and its Results: with 18 Chromolithographed Plates.” South Carolina: Nabu Press, USA, (2012).
2. Schummer, A. “Ein Neues Mittel (“Plastoid”) und Verfahren Zur Herstellung Korrosionsanatomischer Präparate.” *Anat Anz*. 81 (1935): 177-201.
3. Taniguchi, Yoshiyuki, Yoshikuni Ohta and Shigeru Tajiri. “New Improved Method for Injection of Acrylic Resin.” *Okajimas Folia Anat Jpn*. 24 (1952): 259-267.
4. Kus, J. “The History of Injection Methods in the Morphological Sciences.” *Folia Morpholia*. 27 (1969): 134-146.
5. Thompsett, DH. “Anatomical Techniques.”(2nd edn). Scotland: E & S Livingstone, Edinburgh, (1970).
6. Murakami, T. “Application of the Scanning Electron Microscope to the Study of the Fine Distribution of the Blood Vessels.” *Arch Histol Jpn*. 32 (1971): 445-454.
7. Murakami, T. “Pliable Metacrylate Casts of Blood Vessels: Use in a Scanning Electron Microscope Study of the Microcirculation in Rat Hypophysis.” *Arch Histol Jpn*. 38 (1975): 151-168.
8. Nopanitaya, Waykin, JG Aghajanian and LD Gray. “An Improved Plastic Mixture for Corrosion Casting of the Gastrointestinal Microvascular System.” *Scan Electron Microsc*. (1979): 751-755.
9. Murakami, Takuro, Tatsuya Itoshima, Kusukuma Hitomi, and Aiji Ohtsuka, et al. “A Monomeric Methyl and Hydroxypropyl Methacrylate Injection Medium and its Utility in Casting Blood Capillaries and Liver Bile Canaliculi for Scanning Electron Microscopy.” *Arch Histol Jpn*. 47 (1984): 223-237.
10. Aharinejad, SH, and A Lametschwandtner. “Principles and Fundamentals of Microvascular Corrosion Casting for SEM Studies.” In: Microvascular Corrosion Casting in Scanning Electron Microscopy. Springer (eds), Vienna, Austria. 6 (1992): 170-193.
11. Gannon, Bren J. “Preparation of Microvascular Corrosion Media: Procedure for Partial Polymerization of Methyl Methacrylate Using Ultraviolet Light.” *Biomed Res*. (1981): 227-233.
12. Thomas, Krucker, Axel Lang, and Eric P Meyer. “New Polyurethane-Based Material for Vascular Corrosion Casting with Improved Physical and Imaging Characteristics.” *Microsc Res Tech*. 69 (2006): 138-147.
13. Eberlova, L, V Liska, H Mirka, and T Gregor, et al. “Porcine Liver Vascular

Bed in Biodur E20 Corrosion Casts." *Folia Morphol.* 75 (2016): 154-161.

14. Weiger, T, A Lametschwandtner and P Stockmayer. "Technical Parameters of Plastics (Mercox CL-2B and various methylmethacrylates) Used in Scanning Electron Microscopy of Vascular Corrosion Casts." *Scan Electron Microsc*. (1986): 243-252.
15. Sims, PA, and RM Albrecht. "Improved Tissue Corrosion of Vascular Casts: A Quantitative Filtration Method Used to Compare Tissue Corrosion in Various Concentrations of Sodium and Potassium Hydroxide." *Scanning Microsc*. 7 (1993): 637-642.
16. Miodonski, AJ, KC Hodde and C Bakker. "Rasterelektronenmikroskopie Von Plastik-Korrosions-Präparaten: Morphologische Unterschiede Zwischen Arterien Und Venen." Berichte Elektronenmikroskopische Direktabbildung Von Oberflächen 9 (1976): 435-442.
17. Levesque, Murina J, Fredrick Cornhill, and Robert M Nerem. "Vascular Casting. A New Method for the Study of the Arterial Endothelium." *Atherosclerosis*. 34 (1979): 457-467.
18. Nerem, Robert M, Murina J Levesque, and Fredrick Cornhill. "Vascular Endothelial Morphology as an Indicator of the Pattern of Blood Flow." *J Biomech Eng*. 103 (1981): 172-176.
19. Gaudio, E, L Pannarale and G Marinozzi. "An S.E.M. Corrosion Cast Study on Pericyte Localization and Role in Microcirculation of Skeletal Muscle." *Angiology.* 36 (1985): 458-464.
20. Hodde, KC, DA Steeber and RM Albrecht. "Advances in Corrosion Casting Methods." *Scanning Microsc*. 4 (1990): 693-704.
21. Ohtani, O. "Microcirculation of the Pancreas: A Correlative Study of Intravital Microscopy with Scanning Electron Microscopy of Vascular Corrosion Casts." *Arch Histol Japn*. 46 (1983): 315-325.
22. Ohtani, O. "Review of Scanning Electron and Light Microscopic Methods in Microcirculation Research and their Application in Pancreatic Studies." *Scan Electron Microsc*. (1984): 653-661.
23. Lametschwandtner, A, U Lametschwandtner and T Weiger. "Scanning Electron Microscopy of Vascular Corrosion Casts--Technique and Applications." *Scanning Microsc*. (1984): 663-695.
24. Ohta, Y, H Okuda, F Suwa, and S Okada, et al. "Plastic Injection Method for Preparing Microvascular Corrosion Casts for SEM and its Practical Application." *Okajimas Folia Anat Jpn*. 66 (1990): 301-311.
25. Aharinejad, SH and A Lametschwandtner. "Microvascular Corrosion Casting in Scanning Electron Microscopy."(edn). New York: Springer Verlag, Wein (1992).
26. Aharinejad, S and P Böck. "Appearance of Venous Sphincters in the Pulmonary Microvascular Bed of Normotensive and Spontaneously Hypertensive Rats." *Scanning Microsc*. 6 (1992): 865-873.
27. Motta, P, Takuro Murakami, and H Fujita. "Scanning Electron Microscopy of Vascular Casts: Methods and Applications." Kluwer Academic Publishers, Boston-Dordrecht, London (1992).
28. Hossler, Fred E, and John E Douglas. "Vascular Corrosion Casting: Review of Advantages and Limitations in the Application of Some Simple Quantitative Methods." *Microsc Microanal*. 7 (2001): 253-264.
29. Haenssgen, Kati, Andrew N Makanya, and Valentin Djonov. "Casting Materials and their Application in Research and Teaching." *Microsc Microanal*. 20 (2014): 493-513.
30. Lametschwandtner, Alios, and Ursula Lametschwandtner. "Historical Review and Technical Survey of Scanning Electron Microscopy of Vascular Casting and Scanning Electron Microscopy." In: Motta PM, Murakami T and H Fujita (eds), Scanning Electron Microscopy of Vascular Casts: Methods and Applications. Kluwer Academic Publishers, Boston, London, (1992): 1-11.
31. Malkusch, W, MA Konerding, B Klapthor and J Bruch. "A Simple and Accurate Method for 3-D Measurements in Microcorrosion Casts Illustrated with Tumour Vascularization." *Anal Cell Pathol*. 9 (1995): 69-81.
32. Minnich, B, H Leeb, EWN Bernroider and Alios Lametschwandtner. "Three-Dimensional Morphometry in Scanning Electron Microscopy: a Technique for Accurate Dimensional and Angular Measurements of Microstructures using Stereopaired Images and Digital Image Analysis." *J Microsc*. 195 (1999): 23-33.
33. Minnich, B, and Alios Lametschwandtner. "Lengths Measurements in Microvascular Corrosion Castings: Two-Dimensional Versus Three-Dimensional Morphometry." *Scanning*. 22 (2000): 173-177.
34. Lametschwandtner, Alios, B Minnich, B Stöttinger and WD Krautgartner. "Analysis of Microvascular Trees by Means of Scanning Electron Microscopy of Vascular Casts and 3D-Morphometry." *Ital J Anat Embryol*. 110 (2005): 87-95.
35. Manelli, A, S Sangiorgi, E Binaghi and M Raspanti. "3D Analysis of SEM Images of Corrosion Casting Using Adaptive Stereo Matching." *Microsc Res Tech*. 70 (2007): 350-354.
36. Steenkiste, Christophe Van, Bram Trachet, Christophe Casteleyn, and Denis van Loo, et al. "Vascular Corrosion Casting: Analyzing Wall Shear Stress in the Portal Vein and Vascular Abnormalities in Portal Hypertensive and Cirrhotic Rodents." *Lab Invest*. 90 (2010): 1558-1572.
37. Murray, Cecil D. "The Physiological Principle of Minimum Work Applied to the Angle of Branching of Arteries." *J Gen Physiol*. 207 (1926): 835-841.
38. Stöttinger, Bernhard, Martin Klein, Bernd Minnich, and Alois Lametschwandtner. "Design of Cerebellar and Nontegmental Rhombencephalic Microvascular Bed in the Sterlet, Acipenser Ruthenus: A Scanning Electron Microscope and 3D Morphometry Study of Vascular Corrosion Casts." *Microsc Microanal*. 12 (2006): 376-389.
39. Ditrich, H, and H Splechtna. "Scanning Electron Microscopy of Vascular Corrosion Casts in Comparative Studies on Renal Vascular Structure." *Scanning Microsc*. 1(1987): 1339-1347.
40. Ditrich, H, and H Splechtna. "Kidney Structure Investigations Using Scanning Electron Microscopy of Corrosion Casts: A State of the Art Review." *Scanning Microsc*. 4 (1990): 943-956.
41. Cecon, Stephan, Bernd Minnich, and Alois Lametschwandtner. "Vascularization of the Brains of the Atlantic and Pacific Hagfishes, Myxine Glutinosa and Eptatretus Stouti: A Scanning Electron Microscope Study of Vascular Corrosion Casts." *J Morphol*. 253 (2002): 51-63.
42. Lametschwandtner, Alios, and Bernd Minnich. "Microvascular Anatomy of the Brain of the Adult Pipid Frog, Xenopus Laevis (Daudin): A Scanning Electron Microscopic Study of Vascular Corrosion Casts." *J Morphol*. 297 (2018): 950-969.
43. Kleiter, N, and Alios Lametschwandtner. "Microvascularization of the Cerebellum in the Turtle, Pseudemys Scripta Elegans (Reptilia). A Scanning Electron Microscope Study of Microvascular Corrosion Casts, Including Stereological Measurements." *Anat Embryol*. 191 (1995): 145-153.
44. Neumaier, C. and Alios Lametschwandtner. "The Vascularization of the Pituitary Gland in the Chicken (Gallus domesticus). A Scanning Electron Microscope Study of Vascular Corrosion Casts." *Arch Histol Cytol*. 57 (1994): 213-233.
45. Weber, Bruno, Anna Lena Keller, Johannes Reichold, and Nikos K Logothetis. "The Microvascular System of the Striate and Extrastriate Visual Cortex of the Macaque." *Cereb Cortex*. 18 (2008): 2318-2330.
46. Duvernoy, HM, S Delon and JL Vannson. "The Vascularization of the Human Cerebellar Cortex." *Brain Res Bull*. 11 (1983): 419-480.
47. Schraufnagel, DE and KR Patel. "Sphincters in Pulmonary Veins. An Anatomic Study in Rats." *Am Rev Respir Dis*. 141 (1990): 721-716.
48. Aharinejad, S and P Böck. "Luminal Constrictions on Corrosion Casts of Capillaries and Postcapillary Venules in Rat Exocrine Pancreas Correspond to Pericyte Processes." *Scanning Microsc*. 6 (1992): 877-883.
49. Lametschwandtner, Alios and Bernd Minnich. "Renal Microvasculature in the Adult Pipid Frog, Xenopus Laevis: A Scanning Electron Microscope Study of Vascular Corrosion Casts." *J Morphol*. 281 (2020): 725-736.
50. Casellas, D, M Dupont, B Jover and A Mimran. "Scanning Electron Microscopic Study of Arterial Cushions in Rats: A Novel Application of the Corrosion-Replication Technique." *Anat Rec*. 203 (1982): 419-428.
51. Phillips, MN, GT Jones, van Rij AM and M Zhang. "Micro-Venous Valves in the Superficial Veins of the Human Lower Limb." *Clin Anat*. 17 (2004): 55-60.
52. Lametschwandtner, Alios, and P Simonsberger. "Light and Scanning Microcopial Studies of the Hypothalamo-Adenohypophysial Portal Vessels of the Toad Bufo bufo (L.)." *Cell Tissue Res*. 162 (1975): 131-139.

53. Bergland, RM, and RB Page. “Can the Pituitary Secrete Directly to the Brain? (Affirmative anatomical evidence).” *Endocrinology.* 102 (1978): 1325-1338.

54. Gross, PM, MG Joneja, JJ Pang, and TM Polischuk, et al. “Topography of Short Portal Vessels in the Rat Pituitary Gland: A Scanning Electron-Microscopic and Morphometric Study of Corrosion Cast Replicas.” *Cell Tissue Res*. 272 (1993): 79-88.

55. Carretero, A, H Ditrich, M Navarro and J Ruberte. “Afferent Portal Venous System in the Mesonephros and Metanephros of Chick Embryos: Development and Degeneration.” *Anat Rec*. 247 (1997): 63-70.

56. Ohtani, O, and I Naito. “Renal Microcirculation in the Bullfrog, Rana Catesbeiana. A Scanning Electron Microscope Study of Vascular Casts.” *Arch Histol Japn*. 43 (1980): 319-330.

57. Ohtani, O, T Ushiki, H Kanazawa and T Fujita. “Microcirculation of the Pancreas in the Rat and Rabbit with Special Reference to the Insulo-Acinar Portal System and Emissary Vein of the Islet.” *Arch Histol Japn*. 49 (1986): 45-60.

58. Ohtani, O, and QX Wang. “Comparative Analysis of Insulo-Acinar Portal System in Rats, Guinea Pigs, and Dogs.” *Microsc Res Tech*. 37 (1997): 489-496.

59. Höpner, JP, and Alios Lametschwandtner. “Microvascularization of the Pancreas in Larval and Adult Xenopus laevis – Histomorphology and Scanning Electron Microscopy of Vascular Corrosion Casts.” *Arch Histol Cytol*. 76 (2016): 35-52.

60. Shi, YB. “Amphibian Metamorphosis: From Morphology to Molecular Biology.” New Jersey: Wiley–Blackwell, USA, (2000).

61. Rhodin, JA, and Alios Lametschwandtner. “Circulatory Pattern and Structure in the Tail and Tail Fins of Xenopus Laevis Tadpoles.” *J Submicrosc Cytol Pathol*. 25 (1993): 297-318.

62. Lametschwandtner, Alois, Monika Höll, Heidi Bartel, and Vipavee Anupunpisit, et al. “Maturation of the Gastric Microvasculature in Xenopus Laevis (Lissamphibia, Anura) Occurs at the Transition from the Herbivorous to the Carnivorous Lifestyle, Predominantly by Intussusceptive Microvascular Growth (IMG): A Scanning Electron Microscope Study of Microvascular Corrosion Casts and Correlative Light Microscopy.” *Anat Sci Int*. 87 (2012): 88-100.

63. Aichhorn, H, and Alios Lametschwandtner. “Vascular Regression During Amphibian Metamorphosis--A Scanning Electron Microscope Study of Vascular Corrosion Casts of the Ventral Velum in Tadpoles of Xenopus Laevis Daudin.” *Scanning*. 18 (1996): 447-455.

64. Minnich, Bernd, Heidi Bartel, and Alois Lametschwandtner. “How a Highly Complex Three-Dimensional Network of Blood Vessels Regresses: The Gill Blood Vascular System of Tadpoles of Xenopus During Metamorphosis. A SEM Study on Microvascular Corrosion Casts.” *Microvasc Res*. 64 (2002): 425-437.

65. Ditrich, H, and H Splechtna. “The Opisthonephric Blood Vascular System of the Chicken Embryo as Studied by Scanning Electron Microscopy of Microvascular Corrosion Casts and Critical Point Dried Preparations.” *Scanning Microsc*. 3 (1989): 559-564.

66. DeRuiter, M C, A C Gittenberger-de Groot. “Technical Improvements in Corrosion Casting of Small Specimens: A Study on Mesonephric Tubules and Vessels of Chicken Embryos.” *Scanning Microsc*. 9 (1995): 307-308.

67. Hiruma, T, and R Hirakow. “Formation of the Pharyngeal Arch Arteries in the Chick Embryo. Observations of Corrosion Casts by Scanning Electron Microscopy.” *Anat Embryol (Berl)*. 191 (1995): 415-423.

68. Hiruma, T. “Formation of the Ocular Arteries in the Chick Embryo: Observations of Corrosion Casts by Scanning Electron Microscopy.” *Anat Embryol (Berl)*. 193 (1996): 585-592.

69. Carretero, A, H Ditrich, M Navarro, and H Splechtna, et al. “Technical Improvements in Corrosion Casting of Small Specimens: A Study on Mesonephric Tubules and Vessels of Chicken Embryos.” *Scanning Microsc*. 7 (1993): 1333-1337.

70. Kondo, S. “Microinjection Methods for Visualization of the Vascular Architecture of the Mouse Embryo for Light and Scanning Electron Microscopy.” *J Electron Microsc (Tokyo)*. 47 (1998): 101-113.

71. Navarro, M, A Carretero, L Canut, and FJ Perez-Aparicio, et al. “Injection Technique and Scanning Electron Microscopic Study of the Arterial Pattern of the 20 Gestation Days (G20) Rat Fetus.” *Lab Anim*. 32 (1998): 95-105.

72. Gorczyca, Janusz, Jan A Litwin, Kazimierz Pitynski and Adam J Miodonski. “Vascular System of Human Fetal Pancreas Demonstrated by Corrosion Casting and Scanning Electron Microscopy.” *Anat Sci Int*. 85 (2010): 235-240.

73. Patan, Sybill, Maria J Alvarez, Johannes C Schittny, and Peter H Burri. “Intussusceptive Microvascular Growth: A Common Alternative to Capillary Sprouting.” *Arch Histol Cytol*. 55 (1992): 65-75.

74. Bartel, H, and Alios Lametschwandtner. “Intussusceptive Microvascular Growth in the Lung of Larval Xenopus Laevis Daudin: A Light Microscope, Transmission Electron Microscope and SEM Study of Microvascular Corrosion Casts.” *Anat Embryol (Berl)*. 202 (2000): 55-65.

75. Burri, Peter H, Ruslan Hlushchuk, and Valentin Djonov. “Intussusceptive Angiogenesis: its Emergence, its Characteristics, and its Significance.” *Developmental Dynamics*. 231 (2004): 474-88.

76. Konerding, Moritz A, Barry C Gibney, Jan P Houdek, and Kenji Chamoto, et al. “Spatial Dependence of Alveolar Angiogenesis in Post-Pneumonectomy Lung Growth.” *Angiogenesis*. 15 (2012): 23-32.

77. Giacomini, Arianna, Maximilian Ackermann, Mirella Belleri, and Daniela Coltrini, et al. “Brain Angioarchitecture and Intussusceptive Microvascular Growth in a Murine Model of Krabbe Disease.” *Angiogenesis*. 18 (2015): 499-510.

78. Belle, Janeil, Alexandra Ysasi, Robert D Bennett, and Nenad Filipovic, et al. “Stretch-Induced Intussuceptive and Sprouting Angiogenesis in the Chick Chorioallantoic Membrane.” *Microvasc Res*. 95 (2014): 60-67.

79. Pabst, Andreas Max, Maximilian Ackermann,Willi Wagner, and David Haberthür, et al. “Imaging Angiogenesis: Perspectives and Opportunities in Tumour Research – A Method Display.” *J Craniomaxillofac Surg*. 42 (2014): 915-923.

80. Ackermann, Maximilian, and Moritz A Konerding. “Vascular Casting for the Study of Vascular Morphogenesis.” *Methods Mol Biol*. 1214 (2015): 49-66.

81. Kratky, RG and MR Roach. “Relationship between Aortic Endothelial Cell Morphology and Atherosclerosis in Rabbits.” *Scan Electron Microsc*. (1983): 1461-1466.

82. Kratky RG and MR Roach. “Scanning Electron Microscopy of Early Atherosclerosis in Rabbits Using Aortic Casts.” *Scanning Microsc*. 2 (1988): 465-470.

83. Zeindler, Christine M, Ralph G Kratky, and Margot R Roach. “Quantitative Measurements of Early Atherosclerotic Lesions on Rabbit Aortae from Vascular Casts.” *Atherosclerosis*. 76 (1989): 245-255.

84. Lametschwandtner, Alios, Bernd Minnich, David Kachlik, and Marek Setina, et al. “Three-Dimensional Arrangement of the Vasa Vasorum in Explanted Segments of the Aged Human Great Saphenous Vein: Scanning Electron Microscopy and Three-Dimensional Morphometry of Vascular Corrosion Casts.” *Anat Rec A Discov Mol Cell Evol Biol*. 281 (2004): 1372-1382.

85. Fryczkowski, AW, SE Sato and BL Hodes. “Changes in the Diabetic Choroidal Vasculature: Scanning Electron Microscopy Findings.” *Ann Ophthalmol*. 20 (1988): 299-305.

86. Fryczkowski, AW, BL Hodes and J Walker. “Diabetic Choroidal and Iris Vasculature Scanning Electron Microscopy Findings.” *Int Ophthalmol*. 13 (1989): 269-279.

87. Sangiorgi, S, A Manelli, M Reguzzoni, and M Ronga, et al. “The Cutaneous Microvascular Architecture of Human Diabetic Toe Studied by Corrosion Casting and Scanning Electron Microscopy Analysis.” *Anat Rec (Hoboken)*. 293 (2010): 1639-1645.

88. Gattone, VH, and AP Evan. “Quantitative Renal Vascular Casting in Nephrology Research.” *Scan Electron Microsc*. (1986): 253-262.

89. Burger, PC, DB Chandler, AW Fryczkowski and GK Klintworth. “Scanning Electron Microscopy of Microcorrosion Casts: Applications in Ophthalmologic Research.” *Scanning Microsc.* (1987): 223-231.

90. Polykandriotis, E, S Euler, A Arkudas, and G Pryymachuk, et al. “Regression and Persistence: Remodelling in a Tissue Engineered Axial Vascular

Assembly." *J Cell Mol Med*. 13 (2009): 4166-4175.

91. Rath, Subha N, Andreas Arkudas, Christopher Xf Lam, and Radoslaw Olkowski, et al. "Development of a Pre-Vascularized 3D Scaffold-Hydrogel Composite Graft Using an Arterio-Venous Loop for Tissue Engineering Applications." *J Biomater Appl.* 27 (2012): 277-289.

92. Huling, Jennifer, In Kap Ko, Anthony Atala, and James J Yoo. "Fabrication of Biomimetic Vascular Scaffolds for 3D Tissue Constructs Using Vascular Corrosion Casts." *Acta Biomater*. 32 (2016): 190-197.

93. Grunt, TW, Alios Lametschwandtner, K Karrer and O Staindl. "The Angioarchitecture of the Lewis Lung Carcinoma in Laboratory Mice (a light microscopic and scanning electron microscopic study)." *Scan Electron Microsc*. (1986): 557-573.

94. Grunt, TW, Alios Lametschwandtner, and K Karrer. "The Characteristical Structural Features of the Blood Vessels of the Lewis Lung Carcinoma." *Scan Electron Microsc*. (1986): 575-598.

95. Bugajski, A, M Nowogrodzka-Zagórska, J Leńko and AJ Miodoński. "Angiomorphology of the Human Renal Clear Cell Carcinoma. A Light and Scanning Electron Microscopic Study." *Virchows Arch A Pathol Anat Histopathol*. 415 (1989): 103-113.

96. Konerding, MA, F Steinberg, C van Ackern, and V Budach. "Vascular Patterns of Tumors: Scanning and Transmission Electron Microscopic Studies on Human Xenografts." *Strahlenther Onkol*. 168 (1992): 444-452.

97. Konerding, MA, AJ Miodonski and Alios Lametschwandtner. "Microvascular Corrosion Casting in the Study of Tumor Vascularity: A Review." *Scanning Microsc*. 9 (1995): 1233-1243.

98. Miodoński, AJ, A Bugajski, JA Litwin and Z Piasecki. "Vascular Architecture of Human Urinary Bladder Carcinoma: A SEM Study of Corrosion Casts." *Virchows Arch*. 433 (1998): 145-151.

99. Miodonski, AJ, JA Litwin, M Nowogrodzka-Zagórska and J Gorczyca. "Vascular Architecture of Normal Human Urinary Bladder and its Remodeling in Cancer, as Revealed by Corrosion Casting." *Ital J Anat Embryol*. 106 (2001): 221-228.

100. Djonov, V, AC Andres and A Ziemiecki. "Vascular Remodelling During the Normal and Malignant Life Cycle of the Mammary Gland." *Microsc Res Tech*. 15 (2001): 182-189.

101. Oliveira de Oliveira, Laura Beatriz, Vinícius Faccin Bampi, Carolina Ferreira Gomes, and Jefferson Luis Braga da Silva, et al. "Morphological Characterization of Sprouting and Intussusceptive Angiogenesis by SEM in Oral Squamous Cell Carcinoma." *Scanning*. 36 (2014): 293-300.

102. Castenholz, A, H Zöltzer and H Erhardt. "Structures Imitating Myocytes and Pericytes in Corrosion Casts of Terminal Blood Vessels. A Methodical Approach to the Phenomenon of "Plastic Strips" in SEM." *Mikroskopie*. 39 (1982): 95-106.

103. Aharinejad, SH and P Böck. "Casting with Mercox-Methylmethacrylic Acid Mixtures Causes Plastic Sheets on Elastic Arteries. A Scanning and Transmission Electron Microscopic Study." *Scanning Microsc*. 7 (1993): 629-634.

104. Trachet, Bram, Abigail Swillens, Denis Van Loo, and Christophe Casteleyn, et al. "The Influence of Aortic Dimensions on Calculated Wall Shear Stress in the Mouse Aortic Arch." *Comput Methods Biomech Biomed Engin*. 12 (2009): 491-499.

105. Mondy, William Lafayette, Don Cameron, Jean-Pierre Timmermans, and Nora De Clerck, et al. "Micro-CT of Corrosion Casts for Use in the Computer-Aided Design of Microvasculature." *Tissue Eng Part C Methods*. 15 (2009): 729-738.

106. Debbaut, Charlotte, Patrick Segers, Pieter Cornillie, and Christophe Casteleyn. "Analyzing the Human Liver Vascular Architecture by Combining Vascular Corrosion Casting and Micro-CT Scanning: A Feasibility Study." *J Anat.* 224 (2014): 509-517.

107. Marsh, Donald J, Dmitry D Postnov, Douglas J Rowland, and Anthony S Wexler. "Architecture of the Rat Nephron-Arterial Network: Analysis with Micro-Computed Tomography." *Am J Physiol Renal Physiol*. 313 (2017): 351-360.

How to cite this article: Lametschwandtner, Alois, and Minnich Bernd. "Scanning Electron Microscopy of Vascular Corrosion Casts in Biological and Biomedical Research." *J Morphol Anat Disorder* 5 (2021): 137.