A Comparative Study of Posttraumatic and Prenatal Angio- and Myogenesis in Mammals

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Desynchronization of myo- and angiogenesis is observed after trauma of skeletal muscles. These processes are synchronous during prenatal development (18th day of embryogenesis).

Key Words: *posttraumatic and embryonal myogenesis; myoblasts; muscle tubules; capillaries*

Survival of the skeletal muscles after damage and the size of necrosis are determined not only by regenerative potential of striated muscles. The relationship between angio- and myogenesis after trauma of skeletal muscles is a key factor of the processes occurring in the skeletal muscle after trauma [1,3,5,6].

MATERIALS AND METHODS

Crushed wound of the medial head of the tarsal complex was produced in male albino rats (body weight 300-360 g) by the method [4] under ether anesthesia. The muscles were studied on days 1, 2, 3, 5, 7, and 10 after trauma. The tarsal complex muscles were also studied in 18-day-old embryos. Pieces of the muscles were consecutively fixed in cold formol-sucrose and 1% OsO_4 (buffered solution) and embedded in Araldite. Ultrathin sections were examined in a JEM-7A electron microscope.

RESULTS

Microtubules, myoblasts, symplasts, and young muscle fibers were observed in the skeletal muscle of 18-day-old rat embryo. It should be noted that myoblasts and muscle tubules had no basal membranes. A poorly developed basal membrane was observed only in young muscle fibers (Fig. 1, *a*, *b*). Capillaries and arterioles containing blood cells are present among myogenic elements (Fig. 2). Active formation of capillaries, arterioles, and venules occurs during prenatal development. The forming microvessels have no basal membrane. Endothelial cells moving from one microvessels to another and incorporation of poorly differentiated interstitial cells in the vascular wall are seen (Fig. 2). Thus, electron microscopy studies show that the processes of angio- and myogenesis in 18-day-old rat embryo are synchronous. The presence of cells in the microvessels testifies to the set-up of microcirculation.

On days 3-5 after trauma of skeletal muscles, the processes of myogenesis in adult rats are well pronounced, being represented by differentiating myoblasts and muscle tubules (Fig. 3). Formation of symplasts was observed on days 7-10. Microvascular stases and microthrombi were noted (Fig. 4, *b*). Many capillaries are destroyed, and formed blood elements are lying in the interstitium. These observations indicate that the early post-traumatic myogenesis proceeds under hypoxic conditions, as evidenced by the distinct morphological sings of microcirculatory disturbances (Fig. 4, *b*) in "old" blood vessels when new microvessels had not formed. Regeneration of capillaries: formation of the cones of growth from the "old" blood vessels and development of *de novo* capillaries from poorly differentiated cells of the interstitial space occur during formation of the muscle tubules and primary symplasts. The new microvessels were functionally immature. The cytoplasm of their endothelial cells was filled with

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Fig. 1. Prenatal development of rat skeletal muscles (18th day of gestation). *a*, *b*) joining of myoblasts to the muscle fiber. *MB*) myoblasts; *MF*) muscle fiber, *N*) nucleus. ×5000 (*a*) and ×11,000 (*b*).

ribosomes, polysomes, and young electron dense mitochondria. These cells contained practically no specific organelles (micropinocytotic vesicles) (Fig. 4, *a*).

Our results show that in contrast to an embryo, angio- and myogenesis are desynchronized in an adult organism after trauma: angiogenesis lags 2-3 days behind myogenesis. It can be suggested that myogenic elements are differentiating under hypoxic conditions. Desynchronization of angio- and myogenesis is an important feature of myogenic elements differentiating and developing after trauma. In hypoxia, fibroblasts display a high collagen-producing activity, which results in disintegration of myoblasts and microtubules. Collagen fibrils prevent the formation of symplasts.

Our results do not agree with the finding that myogenesis and revascularization are activated simultaneously on day 3 after injury [7]. At the same time,

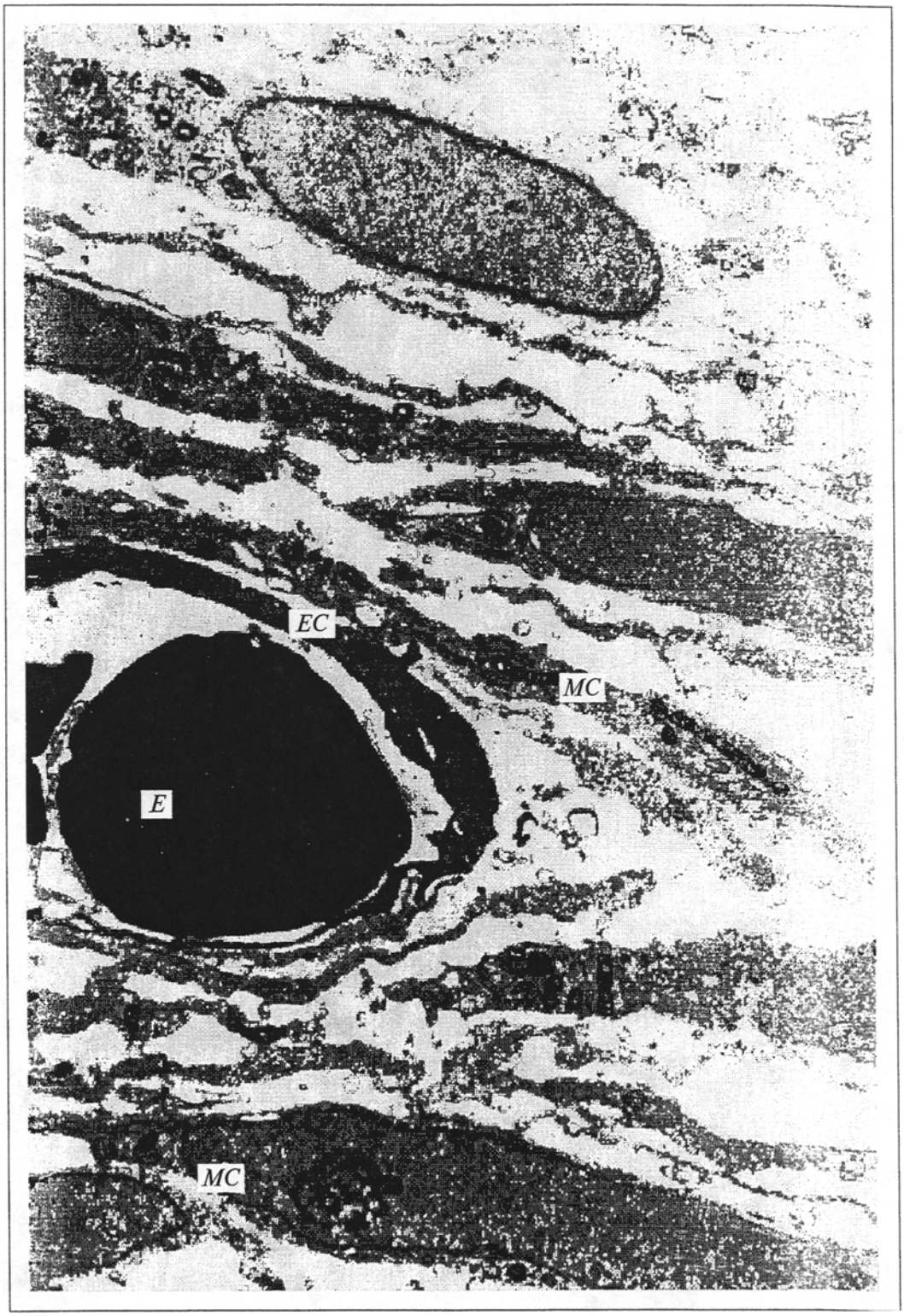

Fig. 2. Microvessel among poorly differentiated cells (18th day gestation). *EC*) endothelial cell; *E*) erythrocyte, *MC*) mesenchymal cells. ×7000.

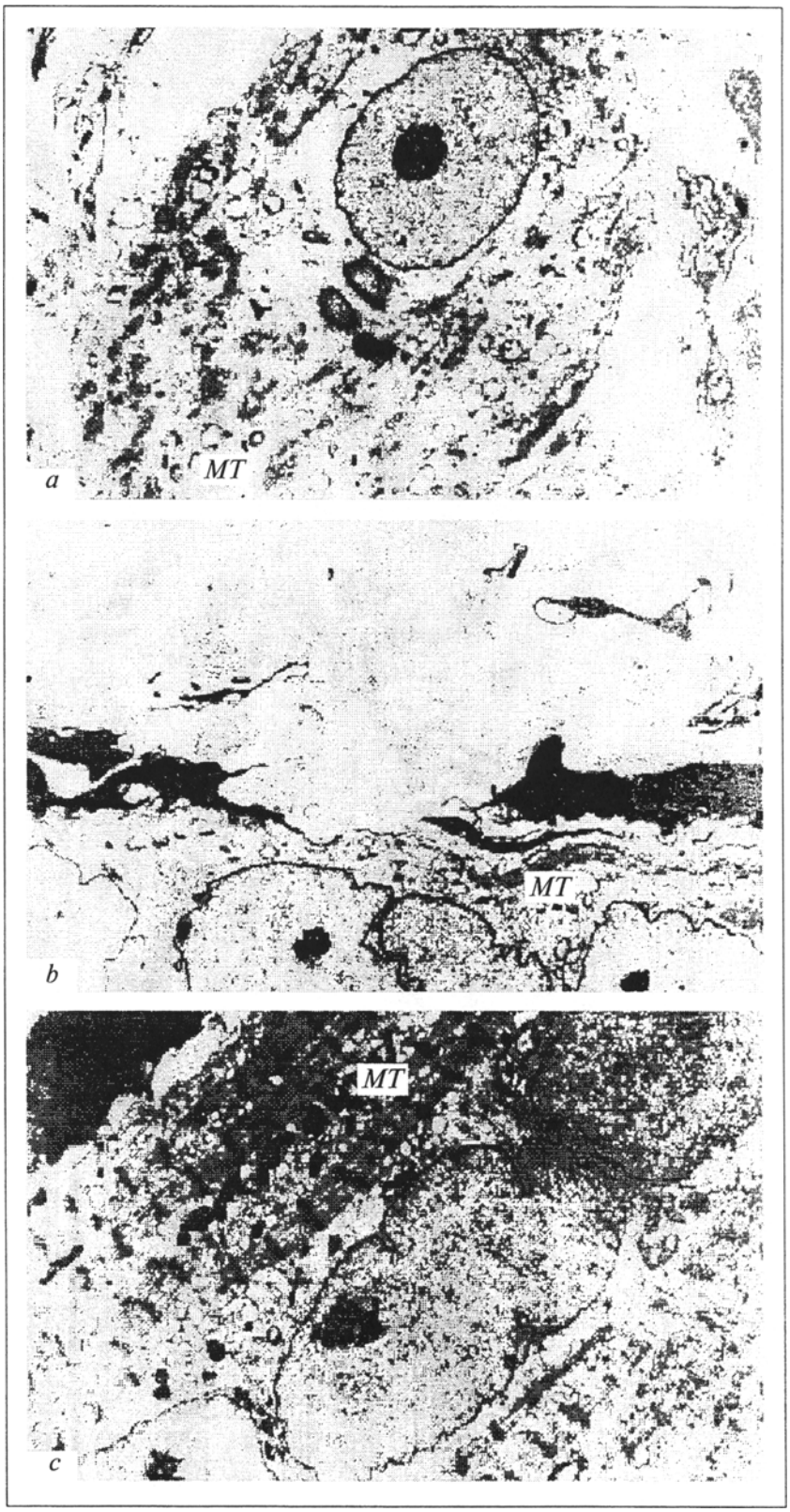

Fig. 3. Post-traumatic myogenesis (day 10 after trauma). *a*) primary muscle tubule (*MT*). Active process of myofibril formation; *b*) muscle tubule among fibroblasts; *c*) mature muscle tubule. ×7000 (*a*, *b*) and ×11,000 (*c*).

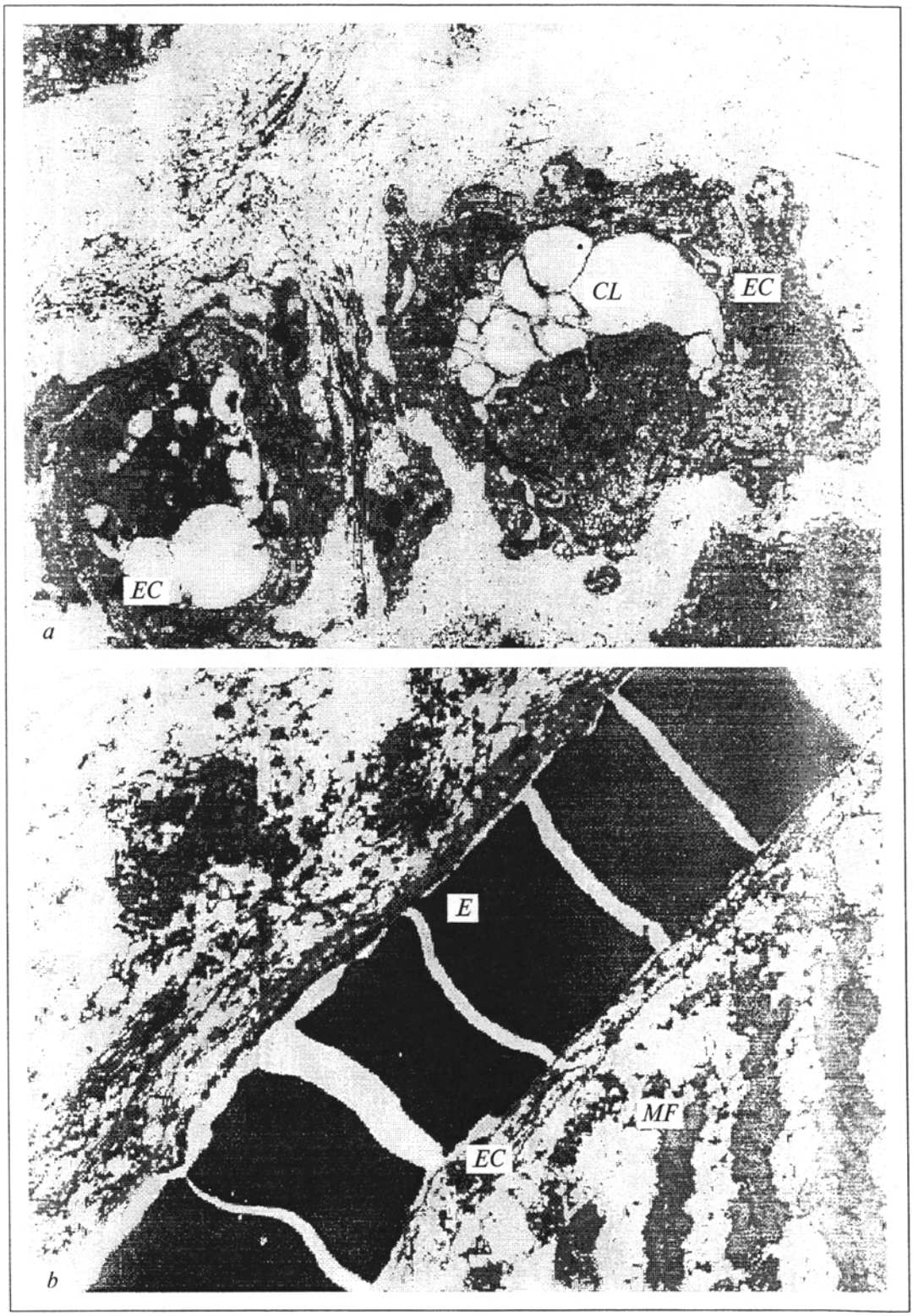

Fig. 4. Ultrastructure of microvessels after the skeletal muscle trauma. *a*) formation of *de novo* capillaries (day 5 after trauma). *CL*) capillary lumen; *EC*) endothelial cell, ×11,000. *b*) formed blood elements in the capillary lumen (day 3 after trauma). *E*) erythrocyte; *MF*) fragments of muscular fiber. ×22,000.

differentiation of satellite cells begins on the 1st day after trauma, while differentiated myoblasts and muscle tubules with active formation of sarcomeres are observed on day 3 [2,3].

REFERENCES

1. A. V. Volodina, N. S. Gurko, and O. M. Pozdnyakov, *Byull. Eksp. Biol. Med.*, **112**, No. 7, 103-106 (1991).
2. A. V. Volodina and O. M. Pozdnyakov, *Ibid.*, **91**, No. 6, 757-759 (1981).
3. A. V. Volodina and O. M. Pozdnyakov, *Ibid.*, **100**, No. 7, 111-114 (1985).
4. V. Kennon, *Problem of Shock* [Russian translation], Moscow - Leningrad (1943).
5. V. V. Kupriyanov, V. A. Mironov, A. A. Mironov, and O. Yu. Gurina, *Angiogenesis* [in Russian], Moscow (1993).
6. V. A. Shakhlamov, *Capillaries* [in Russian], Moscow (1971).
7. D. Miranda, B. C. Yrounds, K. Johv, and C. Megeachi, *Muscle Nerve*, **13**, 305-313 (1990).