DOI: https://doi.org/10.2298/SARH170626154M
UDC: 616.711-001.4

ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Angiogenic capabilities of omentomyelopexy for injured spinal cord revascularization

Ljubodrag Minić[1], Branko Đurović[2,3], Milan Lepić[1,2], Milan Spaić[4], Goran Pavlićević[1,5], Nenad Novaković[1], Nemanja Jaćimović[1], Lukas Rasulić[2,3]

[1]Military Medical Academy, Clinic for Neurosurgery, Belgrade, Serbia;
[2]University of Belgrade, Faculty of Medicine, Belgrade, Serbia;
[3]Clinical Center of Serbia, Clinic for Neurosurgery, Belgrade, Serbia;
[4]Zemun Clinical Hospital Centre, Department of Neurosurgery, Belgrade, Serbia;
[5]University of Defence, Medical Faculty of the Military Medical Academy, Belgrade, Serbia

SUMMARY

Introduction/Objective Increasing incidence of spinal cord injuries presents a very important issue. These patients are usually very young, treatment is very difficult, long, expensive, and, in general, of little success. The aim of this study was to evaluate the angiogenic potential of the omental graft in spinal cord revascularization after the injury.

Methods The study included 19 patients, who underwent a recurrent surgical procedure for pain syndrome or surgical complication, and one patient in whom angiography revealed no flow in the distal part of an omental graft.

Results Our study confirmed angiogenic capabilities of the omental graft placed in the course of omentomyelopexy, for the injured spinal cord revascularization, macroscopically and histopathologically. Study results are limited due to including patients only when the postoperative period was complicated.

Conclusion Our study provides some invasive insight into the angiogenic capabilities, although further (likely less invasive) studies are needed to elucidate more clearly omental angiogenesis in spinal cord injury, and to include patients in whom the procedure went well.

Keywords: omentum; omentomyelopexy; spinal cord injury; angiogenesis; revascularization

INTRODUCTION

Injuries of the vertebral column, spinal cord, and cauda equina are present in 0.7–4% of all traumatic injuries, and 6.3% of traumatic injuries of the skeletal system, and their frequency increases mainly due to traffic accidents [1]. According to the data from Vietnam, missile-caused injuries of these structures were considered to appear in only 1%, although more current results suggest a far more frequent incidence of about 17% of missile injuries during the global war on terrorism [2, 3]. Although increasing incidence of spinal cord injuries (SCI) presents a very important issue, the most important one is the very nature of the injury. These patients are usually very young (approximately 20 years old), treatment is very difficult, long, expensive and, in general, of little success [4, 5].

Development of spinal fusion enabled the vertebral column to be stabilized after the injury, but very little to no improvement was achieved in SCI treatment [6]. Recently, the debate was re-sparked once again, as numerous treatment options have been developed recently, although their impact on spinal cord recovery after injury remained questionable [7].

The role of omental transposition for the brain and spinal cord vascularization was first mentioned in the mid-70s, by Goldsmith et al. [8, 9], and, since then, many authors have suggested various implementations of the omentum in both SCI and degenerative disease of the spine [10, 11, 12].

Due to omental richness in blood and lymphatic vessels and the ability to coalesce the injured area with capillary ingrowth during the first four to six hours, the omentum presents theoretically ideal tissue to revascularize the damaged spinal cord [13]. Omentopexy is a surgical procedure to connect the great omentum with a nearby organ, which induces the arterial circulation in the omental graft, thus causing the arterial circulation improvement in the target organ [14, 15]. Herewith, we have tried to encourage omental transposition for SCI through omentomyelopexy, by evaluating the angiogenic potential of the omental graft in spinal cord revascularization after the injury.

METHODS

Study group and inclusion criteria

The study included 19 patients who underwent a recurrent surgical procedure for pain syndrome or surgical complication [infection, meningoomentocele or cerebrospinal fluid (CSF) fistula], and one patient in whom angiography

Received • Примљено: June 26, 2017
Accepted • Прихваћено: July 20, 2017
Online first: August 4, 2017

Correspondence to:
Lukas RASULIĆ
University of Belgrade
Faculty of Medicine
Clinical Center of Serbia
Clinic for Neurosurgery,
Department for Peripheral Nerve Surgery,
Functional Neurosurgery and Pain Management Surgery
26 Višegradska Street
11000 Belgrade, Serbia
lukas.rasulic@gmail.com

revealed no flow in the distal part of the omental graft. The initial group of patients consisted of 100 patients (89 male and 11 female), treated with omentomyelopexy due to the missile-caused SCI neurological deficit at the Department of Neurosurgery of the Military Medical Academy in Belgrade, Serbia, during a five-year period (1993–1997).

Patients included in the study fulfilled all the criteria: decompressive surgery performed for missile-caused spinal cord injury; omentomyelopexy performed for stabile neurological deficit, after initial decompressive surgery; recurrent surgery for pain syndrome or complication of omentomyelopexy.

The purpose of omentomyelopexy is angiogenesis of the damaged spinal cord, using the multipotent organ of the abdominal cavity, to provide revascularization, and to create adequate conditions for damaged spinal cord remyelization. This would all lead to nerve impulse propagation reestablishment, and consequent neurological improvement [16].

Postoperative pain syndrome was present in seven patients, and it appeared two to five years after the surgery. All the patients suffered from missile injuries of the spinal cord ranging between the T10 and the L2 spinal levels. After the injury, initial treatment included decompressive laminectomy and evacuation of bony fragments from the spinal canal, which was followed by omentomyelopexy 4–17 months after the initial surgery. The treatment option for these patients was microsurgical approach to the dorsal root entry zone (DREZ-otomy) [17].

Meningoomentocele developed in five patients, CSF fistula developed in three, and an infection of the neurosurgical site occurred in three patients. Reoperation was indicated to resolve these complications [18].

RESULTS

Direct intraoperative observation

Surgical treatment of complications also allowed a look into the surgical site to observe and evaluate the omentomyelopexy angiogenesis in vivo. Macroscopic photos were taken, while the small part of the grafted omentum was excised and referred to histopathological analysis to assess the viability and vasculature of the grafted omentum [19].

Splenic artery angiography

Selective angiography of the splenic artery was performed during the early postoperative period (on the 10th day after the surgery) in three patients to determine the vascular competency and to evaluate early angiogenic capabilities of the omental graft. Anastomosis between the omental flap arteries and the vertebral and spinal artery was corroborated in one patient, which confirmed angiogenic capabilities of the transposed omentum [16]. One patient's angiography revealed only abdominal blood vessels, although no signs of graft necrosis were present; a revision was performed only to confirm the graft vitality and blood flow persistence.

Macroscopic appearance

In patients who were re-operated on due to infection, the omental graft appeared pale, volume was reduced to about 50% of the initial value (mainly due to fatty tissue reduction, while the vascular structures were not significantly changed), and active bleeding from the graft surface was noted. On the other hand, re-operation revealed that CSF fistula or meningoomentocele induced no significant changes in the graft macroscopic appearance.

The omental graft in patients who underwent DREZ-otomy due to painful syndrome was also evaluated, and the results are presented in Table 1.

Histopathologic changes in the omental graft

Myxoid changes were present in the omental graft adipose tissue, the connective tissue in the mature lobular adipose tissue, the merging of the fiber striated musculature, the isles of lymphocytic infiltration due to inflammation, as well as histological changes of vascular structures. Newly formed, thin-walled blood vessels of irregular diameter and proliferation of the intima were present Perivascular connective tissue expansion was also present [19].

DISCUSSION

There is no definitive treatment for SCI. None of the treatment options have shown any significant influence to the functional outcome of these patients. Numerous

Table 1. Characteristics of patients in whom a DREZ-otomy was performed for pain syndrome after omentomyelopexy for SCI [17]

Age	Sex	ASIA assessment result	Time from injury to omentomyelopexy (months)	Time to DREZ-otomy after omentomyelopexy (months)	Omental graft vitality
35	M	(C) sensory level T12	4	30	vital
35	M	(B) sensory level T12	9	26	atrophic
27	M	(D) sensory level T12	10	33	vital
25	M	(A) sensory level T12	14	60	disintegrated
29	M	(C) sensory level T12	14	34	vital
31	M	(B) sensory level L2	17	36	atrophic
41	M	(B) sensory level T12	14	42	disintegrated

techniques, including stem cells, collagen implants, and electric devices have been proposed by authors, although not many studies have been performed in human population [20, 21, 22].

Functional outcome is the only parameter significant for the patient, but scientific interest is broader, and any indication of notable positive effect on the spinal cord repair and regeneration is considered to be of the greatest importance.

Our study is unique for its two-way confirmation of the successful implantation of transposed omentum, the angiographic, and direct intraoperative observation [16, 17, 19].

An MRI study by Goldsmith et al. [23] was performed on cats, but also in a patient suffering from SCI, who had omental–collagen bridge reconstruction that connects the proximal and distal ends of the transected spinal cord. The patient in this paper has clinically progressed to the point where she can ambulate with the use of a walker. A spinal cord defect of 4 cm in length showed MRI signs of development of a longitudinal spinal cord connection in the area of the omental–collagen bridge.

This study provides some insight into the interaction of the transposed omentum and the injured spinal cord. Although functional recovery is not exclusively related to the observed and noted changes, the histopathologic and angiogenic capabilities are the basis of the recovery development.

CONCLUSION

Our intraoperative study confirmed angiogenic capabilities of the omental graft placed in the course of omentomyelopexy, for the injured spinal cord revascularization, although study results are definitely diminished due to including only patients in whom there were complications or pain syndrome.

Further (likely less invasive) studies, which would include patients in whom the procedure went well, are needed to provide more insight into omental angiogenesis in SCI.

NOTE

The paper is a part of Dr. Ljubodrag Minić's PhD thesis.

REFERENCES

1. Livshits AV. Surgery of the spinal cord. First American ed. Madison: International Universities Press; 1991.
2. Hardaway RM 3rd. Viet Nam wound analysis. J Trauma. 1978; 18(9):635–43.
3. Blair JA, Patzkowski JC, Schoenfeld AJ, Cross Rivera JD, Grenier ES, Lehman RA Jr., et al. Spinal column injuries among Americans in the global war on terrorism. J Bone Joint Surg Am. 2012; 94(18):e135(1–9).
4. Ignjatović M, Minić L, Cerović S, Ćuk V. [Injuries of the spinal cord]. Vojnosanit Pregl. 1997; 54(6):581–7.
5. Kalsi-Ryan S, Beaton D, Curt A, Popovic MR, Verrier MC, Fehlings MG. Outcome of the upper limb in cervical spinal cord injury: Profiles of recovery and insights for clinical studies. J Spinal Cord Med. 2014; 37(5):503–10.
6. Goldsmith HS. Treatment of acute spinal cord injury by omental transposition: a new approach. J Am Coll Surg. 2009; 208(2):289–92.
7. Heimburger RF. Is there hope for return of function in lower extremities paralyzed by spinal cord injury? J Am Coll Surg. 2006; 202(6):1001–4; discussion 4.
8. Goldsmith HS, Duckett S, Chen WF. Spinal cord vascularization by intact omentum. Am J Surg. 1975; 129(3):262–5.
9. Goldsmith HS, Chen WF, Duckett SW. Brain vascularization by intact omentum. Arch Surg. 1973; 106(5):695–8.
10. Goldsmith HS, Neil-Dwyer G, Barsoum L. Omental transposition to the chronically injured human spinal cord. Paraplegia. 1986; 24(3):173–4.
11. Zheng WJ. [Experimental study on the treatment of spinal cord injury with transplantation of the greater omentum]. Zhonghua wai ke za zhi [Chinese journal of surgery]. 1989; 27(2):93–5, 125.
12. Rafael H. Omental transplantation for cervical degenerative disease. J neurosurgery Spine. 2010; 13(1):139–40.
13. Khosla A, Bowen BC, Falcone S, Quencer RM, Green B. MR of omental myelosynangiosis. Am J Neuroradiol. 1995; 16(2):275–9.
14. Kohiyama R, Yamashita R, Okano R, Kai T, Kuratomi Y, Miyata M. [A successful case of omentopexy for bronchopleural fistula and empyema after right pneumonectomy]. Kyobu Geka. 1994; 47(3):252–5.
15. Ignjatović M, Ćuk V, Minić L, Kostić Z. [History of the development of surgery of the greater omentum]. Vojnosanit Pregl. 1996; 53(5):415–22.
16. Ignjatović M, Pervulov S, Ćuk V, Kostić Z, Minić L. Early angiogenic capabilities of the transposed omental flap after omentomyelopexy. Acta Chir Iugosl. 2001; 48(2):41–3.
17. Spaić M, Minić L, Ćitić R, Lukić Z, Tadić R. [Omentomyelosynangiosis – a direct intraoperative observation]. Vojnosanit Pregl. 2001; 58(3):249–54.
18. Ignjatović M, Ćuk V, Bjelović M, Minić L. [Complications in omentopexy and personal experience with 100 omentomyelopexies]. Vojnosanit Pregl. 2001; 58(6):585–93.
19. Ignjatović M, Cerović S, Ćuk V, Kostić Z, Minić L, Spaić M. Late histological changes in the transposed omental flap. Acta Chir Iugosl. 2001; 48(3):35–8.
20. Minev IR, Musienko P, Hirsch A, Barraud Q, Wenger N, Moraud EM, et al. Biomaterials. Electronic dura mater for long-term multimodal neural interfaces. Science (New York, NY). 2015; 347(6218):159–63.
21. Capogrosso M, Milekovic T, Borton D, Wagner F, Moraud EM, Mignardot JB, et al. A brain-spine interface alleviating gait deficits after spinal cord injury in primates. Nature. 2016; 539(7628):284–8.
22. Fan X, Wang JZ, Lin XM, Zhang L. Stem cell transplantation for spinal cord injury: a meta-analysis of treatment effectiveness and safety. Neural regeneration research. 2017; 12(5):815–25.
23. Goldsmith HS, Fonseca A Jr., Porter J. Spinal cord separation: MRI evidence of healing after omentum-collagen reconstruction. Neurol Res. 2005; 27(2):115–23.

Ангиогенетски потенцијал оментомијелопексије у реваскуларизацији повређене кичмене мождине

Љубодраг Минић[1], Бранко Ђуровић[2,3], Милан Лепић[1,2], Милан Спаић[4], Горан Павлићевић[1,5], Ненад Новаковић[1], Немања Јаћимовић[1], Лукас Расулић[2,3]

[1]Војномедицинска академија, Клиника за неурохирургију, Београд, Србија;
[2]Универзитет у Београду, Медицински факултет, Београд Србија;
[3]Клинички центар Србије, Клиника за неурохирургију, Београд, Србија;
[4]Клиничко-болнички центар Земун, Одељење за неурохирургију, Београд, Србија;
[5]Универзитет одбране, Медицински факултет Војномедицинске академије, Београд, Србија

САЖЕТАК

Увод/Циљ Учестале повреде кичмене мождине су велики проблем. Повређени су обично врло млади, лечење је врло тешко, дуго, скупо и генерално безуспешно.

Циљ овог рада је био да процени ангиогенетски потенцијал транспонираног оментума у реваскуларизацији кичмене мождине после повреде.

Методе Истраживање је обухватило 19 болесника, који су подвргнути поновном хируршком захвату због болног синдрома, хируршке компликације и једног болесника код којег ангиографија није показала проток у дисталном делу режња оментума.

Резултати Студија је потврдила ангиогенетске способности оменталног трансплантата за реваскуларизацију повређене кичмене мождине, макроскопски и хистопатолошки. Резултати студије су ограничени укључивањем само болесника са компликованим постоперативним током и реоперацијом.

Закључак Наша студија пружа одређени увид у ангиогенетске способности оментума, иако су потребне даље мање инвазивне студије како би се пружио бољи увид у оменталну ангиогенезу и укључили испитаници код којих је цео поступак прошао без компликација.

Кључне речи: оментум; оментомијелопексија; повреда кичмене мождине; ангиогенеза; реваскуларизација