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Changes in blood flow within visceral vessels and vessels of the pelvis in patients after stent graft implantation due to an abdominal aortic aneurysm

Zmiany przepływu krwi w obrębie naczyń trzewnych i miednicy u chorych po implantacji stentgraftu z powodu tętniaka aorty brzusznej

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S u m m a r y

Introduction. Surgery of aortic aneurysms and iliac artery aneurysms are associated with postoperative ischemic colitis and corresponding general mortality of 1-8%. Endovascular aneurysm treatment technique using stent graft did not prevent the occurrence of this complication. Using CDD ultrasound for the visceral arteries evaluation, we obtain information on condition of the celiac vascular bed, which allows determining the risk of this complication occurrence.

Material and methods. A prospective study started in reference to Colour Duplex-Doppler (CDD) ultrasound evaluation of the visceral arteries in a group of 60 patients treated for AAA by a stent graft compared to a control group of 78 patients undergoing long-term treatment due to AAA and Leriche syndrome treated with open surgery of aortobifemoral Y-graft implantation. In both groups, CDD ultrasound technique was used in order to evaluate morphological and functional aspect of the visceral arteries: CT, SMA, IMA, and the internal iliac arteries. Initially, 10 patients were examined. Standard parameters of blood flow were determined by Doppler method. Measurements were performed before and after a stent graft implantation. In order to determine the risk of ischemia previously developed so-called indicators of ischemia were used: velocity and resistance.

Results. In the studied material, predictions with CDD ultrasound were made before surgery and these predictions were verified after a surgery, which resulted in clinical confirmation of three cases of mild pelvic ischemia in the form of intermittent claudication, and 1 case of ischemic colitis in the form of transient diarrhoea. The ultrasound risk factors for ischemia were described and the manner of establishing type of ischemia (occlusive/non-occlusive) was developed.

Conclusions. 1) CDD ultrasound evaluation of the visceral arteries is able to predict colonic ischemia after AAA surgery. 2) A prognostic parameter for an occlusive ischemia is the velocity ratio of ischemia (VRI), which is significantly lower than one (<< 1.0), and the secondary resistance ratio of ischemia (RRI), which is higher than one (≥ 1.0). 3) A prognostic parameter for a non-occlusive ischemia is RRI lower than one (≤ 1.0), and secondary VRI higher than one (≥ 1.0). 4) After a stent graft implantation, an occlusive factor of ischemia is dominating. 5) After the AAA surgery, both factors of ischemia are acting, an occlusive and non-occlusive.

Key words: abdominal aortic aneurysm, stent graft, intestinal ischemia, visceral arteries, colour duplex Doppler ultrasound

S t r e s z c z e n i e

Wstęp. Operacje tętniaków aorty i tętnic biodrowych wiążą się z występowaniem pooperacyjnego niedokrwienia okrężnicy i umieralnością ogólną z tego powodu 1-8%. Wewnątrznaczyniowe techniki leczenia tętniaków przy użyciu stentgraftu nie uwolniły chirurgii od tego powikłania. Posługując się badaniem USG-cdd tętnic trzewnych uzyskujemy informacje o stanie łożyska trzewnego, co pozwala określić ryzyko wystąpienia tego powikłania.

Materiał i metody. Rozpoczęto badania prospektywne USG-cdd tętnic trzewnych na 60-osobowej grupie chorych leczonych z powodu TAB stentgraftem w porównaniu do 78-osobowej grupy kontrolnej chorych leczonych odlegle z powodu TAB i zespołu Leriche operacją otwartą wszczepienia protezy aortalnodwuudowej. W obu grupach posługiwano się techniką USG-cdd i oceniano morfologicznie i czynnościowo tętnice trzewne: PT, TKG, TKD, tętnice biodrowe wewnętrzne. Wstępnie przebadano 10 chorych. Określano standardowe parametry przepływu krwi metodą dopplerowską. Pomiary wykonywano przed i po operacji wszczepienia stentgraftu. Dla określenia ryzyka niedokrwienia posługiwano się opracowanymi wcześniej tzw. wskaźnikami niedokrwienia: prędkościowym i oporowym.

Wyniki. W przebadanym materiale prognozowano przy pomocy USG-cdd przed operacją i potwierdzono klinicznie po operacji 3 łagodne przypadki niedokrwienia miednicy pod postacią chromania i 1 przypadek niedokrwienia okrężnicy pod postacią przemijającej biegunki. Opisano ultrasonograficzne czynniki ryzyka niedokrwienia i ustalono sposób określenia rodzaju niedokrwienia (okluzyjne/nieokluzyjne).

Wnioski. 1) USG-cdd tętnic trzewnych pozwala prognozować niedokrwienie okrężnicy po operacji TAB. 2) Parametrem prognostycznym niedokrwienia okluzyjnego jest wskaźnik prędkościowy niedokrwienia (WPN) znacznie niższy do jedności (<< 1,0), a pomocniczym wskaźnik oporowy niedokrwienia (WON) wyższy od jedności (≥ 1,0). 3) Parametrem prognostycznym niedokrwienia nieokluzyjnego jest wskaźnik oporowy niedokrwienia (WON) niższy od jedności (≤ 1,0), a pomocniczym wskaźnik prędkościowy niedokrwienia (WPN) wyższy od jedności (≥ 1,0). 4) Po operacji wszczepienia stentgraftu dominuje czynnik okluzyjny niedokrwienia. 5) Po operacji klasycznej TAB działają oba czynniki niedokrwienia okluzyjny i nieokluzyjny.

Słowa kluczowe: tętniak aorty brzusznej, stentgraft, niedokrwienie jelit, tętnice trzewne, USG color duplex Doppler

INTRODUCTION

In recent years, classical open surgeries for implantation of an artificial bypass graft in treatment of abdominal aortic aneurysms (AAA) have been replaced with a stent graft implantation through an inguinal approach (1).

Inserting prosthesis into the aneurysmal sac-implantation of a stent graft through a small cut at the femoral artery, and then with use of new excellent equipment, through percutaneous puncture of the artery, is commonly used method of protecting the patient against severe complications or death due to the aneurysm rupture (2).

Abdominal aortic aneurysms are quite frequently accompanied by aneurysmal dilation of the iliac arteries, which also require endovascular repair (3).

Endovascular repair surgery of the abdominal aorta with a stent graft (EVAR) related to lower surgical risk, is not free from secondary interventions, also after a few years following implantation (4, 5).

EVAR allows performing the procedure in a patient, who is at high risk of classical surgery (6, 7). During the procedure, the vessels, which are the branches of the abdominal aorta (the inferior mesenteric artery – IMA, the lumbar arteries), or sometimes the branches of the common iliac arteries (internal iliac arteries – IIA), are covered with an implant (8).

Complete morphological evaluation of the trunks of the visceral arteries and iliac arteries is sufficient in CT-scan with administration of the contrast medium (CT angiogram) (9).

Morphological and functional evaluation is possible in ultrasound evaluation using colour duplex Doppler technique (CDD ultrasound) (10). Collaterals and final intestinal arteries remain beyond the range of a direct evaluation (11). Through measurement of some flow ratios (pulsation index – PI, resistance index – RI) we may establish approximate condition of the intestinal resistance bed, which includes arterioles, precapillary sphincters and capillaries (fig. 1) (12).

Evaluation of the visceral arteries under constant technical conditions, and under fasting condition, is conducted before and after surgery (11). A question arises regarding ability to evaluate the visceral bed of the inferior segment of the alimentary tract in patients undergoing endovascular surgeries (13).

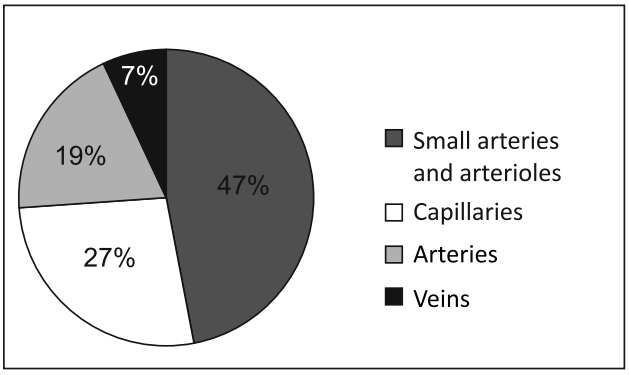

Fig. 1. Vascular components of the peripheral resistance.

AIM OF THE STUDY

Detection of changes in blood flow parameters within the area of the abdominal cavity and the pelvis after stent graft implantation in treatment of the aortic aneurysm comparing to classical surgeries.

MATERIAL AND METHODS

Control group

A control group comprised 78 patients treated with classical surgery method at the Clinic of Vascular Surgery and Angiology in 1995-2002 due to the abdominal aortic aneurysms and aortoiliac occlusive disease. The patients were qualified for surgery based on clinical and ultrasound evaluation. The group included 50 patients with simple aneurysms located below the renal arteries, 5 patients with ruptured aneurysms and 23 with impaired patency of the aorta and the iliac arteries, who belonged to the same risk group in terms of evaluation of the visceral flow hemodynamics.

Studied group

Qualification started in reference to 60 patients treated with aortoiliac stent graft implantation due to abdominal aortic and iliac artery aneurysm. Initially, 10 patients were evaluated (fig. 2).

METHODS

Previous experience gained in evaluation of the control group was transferred to a current studied group in order to conduct comparative analysis.

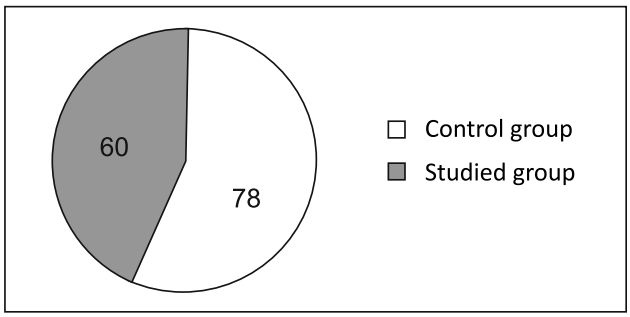

Fig. 2. Material.

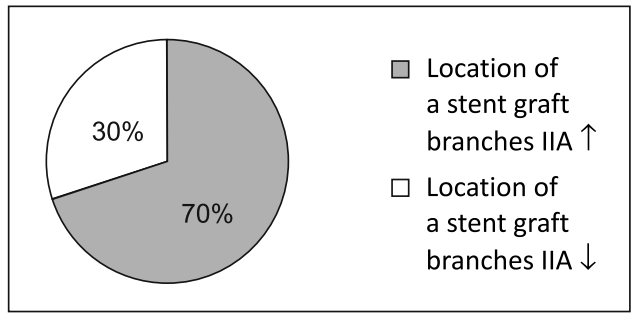

Fig. 3. Classification of the studied group by type of the stent graft.

All fasted patients underwent standard CDD ultrasound study, which was focused on results of morphological and functional evaluation of the visceral arteries and the iliac arteries. Ultrasound machine Siemens Antares Premium and a broad-band probe convex 5 MHz were used.

Basic study includes evaluation of the coeliac trunk (CT), the superior mesenteric artery (SMA), the inferior mesenteric artery (IMA), and the internal iliac arteries (IIA).

Morphological evaluation includes detecting and establishing percent of stenosis of the visceral artery.

Functional evaluation includes quantitative and qualitative assessment of flow with support of analysis of the blood flow velocity using Fourier analysis curve, automatically performed by the ultrasound machine.

Quantitative assessment relates to the level of the systolic velocity (SV), average velocity (AV), end diastolic velocity (EDV), resistance index (RI), and pulsation index (PI).

Qualitative assessment (nature of the flow) includes detecting flow direction, grouping velocity components above or below the baseline, recognizing high resistance flow or low resistance flow, and establishing type of a flow phase (single-phase, two-phase, three-phase).

Using so-called ultrasound ischemia ratios established in a control group (velocity ratio of ischemia (VRI) and resistance ratio of ischemia (RRI)), it was planned that after evaluation of the whole material, the risk of a potential ischemia would be determined and form of ischemia would be predicted (occlusive or non-occlusive ischemia).

$$\{VRI = \frac{V\,tkd}{V\,tkg}, \qquad RRI = \frac{RI\,tkd}{RI\,tkg}\}$$

RESULTS

10 patients, who underwent endovascular aneurysm repair (EVAR) procedure, have been examined so far. In 70% of patients stent graft was implanted into the aorta and the common iliac arteries, and in 30% of patients it was implanted into the aorta and the external iliac arteries (EIA) (fig. 3).

IMA was initially patent in 80% of patients. Similar results were obtained in the control group. In classical surgery, the straight prosthesis was implanted in 75%, and branched prosthesis in 25% of the patients (fig. 4), and IMA was patent in 93% of cases.

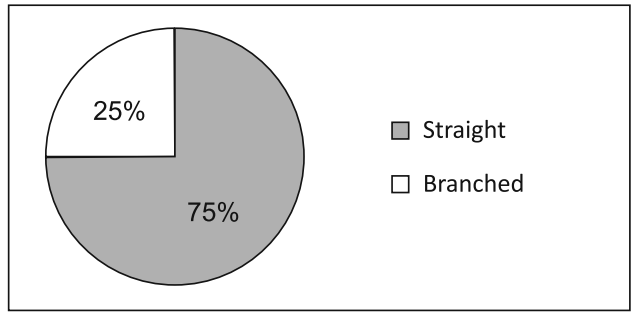

Fig. 4. Classification of the control group by type of the prosthesis.

Based on results of ultrasound evaluation, it was predicted that symptoms of ischemia in the pelvis and the colon would occur in all patients with the prosthesis, which branches were placed in EIA (30%) – IIA coverage. The risk of ischemia was established by visualizing common iliac artery aneurysms reaching the orifices of IIA.

The risk group included the patients with SMA stenosis exceeding 60%. High degree stenoses in SMA were not detected. Small and medium stenoses located in the initial segments, were caused by laminae coming out of the aortic wall.

Superiority in flow parameters of IMA over SMA was established before surgery in 3 patients. No significant morphological and functional changes were detected in CT; therefore, the role of this artery was omitted in perfusion of the pelvis and the colon.

Based on clinical evaluation, signs of ischemia in pelvis were established in 2 patients in form of pelvic claudication. Claudication and postoperative diarrhoea without signs of rectal bleeding occurred in 1 patient. The diarrhoea receded after 5 days. In all 3 patients with mild symptoms of ischemia (30%), the claudication was present on the day of discharge from the hospital. The symptoms occurred in 2 patients with the prosthesis in EIA and in 1 patient due to primary occlusion and stenosis in IIA.

Stenoses in IIA were located in places of branching off. Single aneurysm of the right IIA was located, and

then it was covered with a branch. In the control group, half of the patients revealed abnormalities within IIA: stenoses, one- or two-sided occlusions, aneurysms.

In the studies group, we established that there was no difference in flow parameters in the arteries without stenoses and in the ones with stenoses comparing to the control group, and similarly, statistically significant increase in systolic velocity in SMA and its statistically significant increase or decrease in IMA and decrease in IIA, comparing to reference value for healthy subjects.

Similarly, RI values in CT, SMA, and IIA in both groups oscillated at higher levels comparing to reference value for healthy subjects. In cases, where parametric superiority of IMA occurs, the flow reveals low-resistance, and in SMA it reveals high-resistance. No other differences in reference to IMA were observed comparing to reference value for healthy subjects.

Before a surgery, it was observed in patients at risk of ischemia, who belonged to the control group, that flow in IMA revealed signs of low-resistance, and in SMA, it revealed signs of high-resistance. These patients demonstrated the highest number of indications for repeated implantation into IMA.

In 3 patients from the studied group, symptoms of ischemia were confirmed by results of ultrasound measurements of ratios of ischemia (VRI and RRI).

Detected values of PI in both groups oscillated at the similarly higher levels than it did in healthy subjects.

DISCUSSION

In studied group, ultrasound evaluation is a method of choice in detection and control of AAA (14). Specificity and sensitivity of ultrasound evaluation in detection of AAA reaches 100%. Disadvantage of ultrasound method is the fact that the aorta and its collaterals are not visible due to obesity or flatulence. There is a phenomenon of variable evaluation of the diameter and morphology of the wall depending on experience of an evaluating person. Morphological evaluation of suprarenal and subrenal part, para-aortic area and detection of iliac artery aneurysms are applicable (9, 15-17). If there is imminent need to perform surgical intervention, we perform basic preoperative evaluation – CT angiogram. CT angiogram allows selecting surgical method (classical, endovascular) and correct measurement in order to select an appropriate prosthesis for EVAR procedure (18).

In 30-day observation following classical surgery, general mortality rate is approximately 1-8%. Rate of other complications reaches 13-40%. Disturbance of intestinal function, ischemia and occlusion occur in 2-11% of cases (19). Special complication with general mortality rate of 2% is a colonic ischemia. Incidence of postoperative colonic ischemia reaches 11-36% after classical elective surgeries and 40-60% after surgeries performed in ruptured aneurysms (20). Mortality rate is 50% after elective surgeries and 90% after surgeries performed in ruptured aneurysms (11, 21, 22).

Previous comparison of results obtained in ultrasound evaluation of the visceral arteries in the control group with postoperative results of fibersigmoidoscopy (FSS), allowed determining the risk of ischemia. Indications were established for protecting perfusion of the colon by reimplantation of IMA to the vascular prosthesis. Necessity to use the aortobifemoral Y-graft, if IMA is ligated and reversed inflow is impaired to both IIA, was considered as an indication for implantation of IMA to the prosthesis. Ultrasound indications included: hemodynamically significant, average or large SMA stenosis, large CT stenosis coexisting with SMA stenosis, parametric superiority of flow in normal IMA over the flow in SMA, impaired inflow to IIA, anatomical anomalies of the visceral arteries (documented lack of connections in collateral circulation).

In case of less invasive EVAR method, in postoperative 30-day observation, general mortality rate is 1.2-4.6%. Percentage of cardiological complications is lower – 3.3%, renal complications up to 5.5% and local complications up to 9-16% (23). It is difficult to define incidence of specific complications, which include internal leaks outside of the prosthesis lumen (endoleaks). They lead to filling the aneurismal sac, endograft migration and they contribute to the aneurysm rupture in later period (24, 25).

Covering IMA and IIA with a stent graft results in ischemia in the intestines and the pelvis. Symptoms of ischemia with low and medium progression are associated with occurrence of the rest pain and exercise pain of the hips (pelvic claudication) and disturbed defecation. In advanced ischemia, typical symptoms occur and they include severe pain, abdominal bloating, diarrhoea and bleeding from the final segment of the gastrointestinal tract, worsening in general condition, gradual development of multiorgan failure (MOF) with respiratory failure and renal failure (26, 27).

Approximately 20% of EVAR in ruptured aneurysms are followed by an abdominal compartment syndrome (ACS), which is an effect as well as a cause of prolonged non-occlusive ischemia of the intestines, which leads to necrosis (28-30).

Furthermore, about 11% of patients suffer from ischemia of the spinal cord, which in mild forms lead to the urine retention, and in acute forms it leads to a lower limb paralysis (31).

Contrast medium used before surgery in CT angiography and during surgery intensifies renal failure caused by lowered flow, hypotension and embolism resulted from thrombi of the aortic aneurysm (32, 33).

In the studied group after EVAR, except for 3 cases of mild ischemia, one patient suffered from transient renal failure, which was controlled with intravenous infusions of fluids. All patients were safely discharged from the hospital.

There are two factors for occurrence of the ischemia of the colon – occlusive factor and non-occlusive factor. An occlusion is referred to in case of primary obstruc-

tion of IMA trunk or secondary obstruction (ligation, orifice covering). Non-occlusive ischemia occurs if hypoxia is the main factor, which causes opening precapillary sphincters (in order to omit capillaries) and severe contraction of the final intestinal arteries (34, 35).

During classical surgery of the aneurysm, both causes of ischemia are acting. A surgeon performs IMA ligation in coexisting lack of good inflow to IIA, and low cardiac output, loss of blood, and furthermore, manipulation in intestines activate a cascade of pathophysiological phenomena in the intestinal wall leading to ischemia, which spreads from the top of intestinal villi to the outside of the wall (fig. 5). The tasks of therapeutic team include ensuring sufficient flow in the visceral bed and eliminating non-occlusive causes (11, 36).

Patency in IMA should be restored and this artery should be implanted to the prosthesis at limited inflow to IIA. Such indication is present during classical surgery with aortobifemoral Y-graft implantation. Non-occlusive factor is limited by maintaining normal blood pressure within perioperative period, avoiding angiospastic drugs, normovolemia, and short duration of the procedure. Prolonged action of non-occlusive factors causes occurrence of progressive ischemia of the intestinal wall within postoperative period, which is manifested with musculature paralysis and flatulence in the intestines.

Postoperative evaluation of FSS in patients after EVAR procedure on ruptured aneurysms revealed 25% of ischemic complications (35, 36).

Experience regarding mechanism of the intestinal ischemia, which occurs after classical surgeries, suggests that in case of the elective EVAR procedures, ischemia is caused by more intensive action of occlusive factor. It results from primary or developed occlusion of IMA and closure of IIA orifices (extended branches of a stent graft).

In case of EVAR procedure in treatment of ruptured aneurysms, both main factors of ischemia are acting and they are accompanied by ACS. There is high risk of ischemia in such case (30).

Within the scope of hemodynamic evaluation, surgical implantation of the straight graft for AAA repair is comparable with EVAR with fixation of the endograft

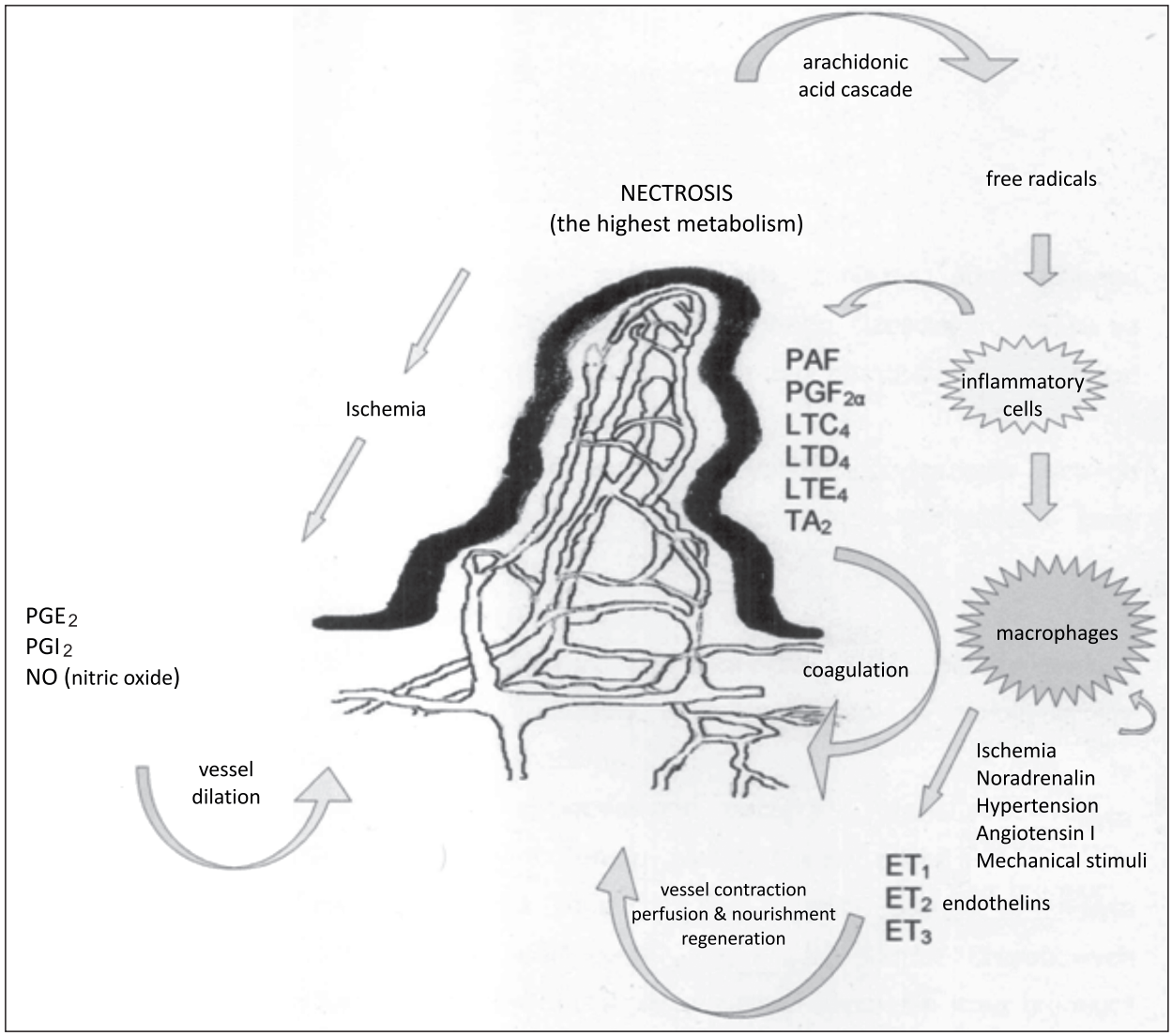

Fig. 5. Mechanisms of the intestinal wall ischemia – the intestinal villus.

branches in the common iliac arteries above IIA orifices. In both types of procedures, IMA is eliminated. As it was demonstrated in both groups, such cases do not result in occurrence of clinical symptoms of the intestinal ischemia in the control group and in occurrence of the clinical symptoms of the intestinal and pelvic ischemia in the studied group. Maintaining patency of at least one IIA prevents occurrence of symptomatic ischemia.

Postoperative FSS evaluation with collection of sections in the control group revealed I° ischemia of the sigmoid colon in case of additional action of non-occlusive factor.

It was established that during an elective surgery for implantation of the straight graft in AAA repair, IMA is not routinely implanted in the prosthesis. Such management proved correct in postoperative FSS.

It was detected in the control group that in cases of implantation of the straight graft in AAA repair, ultrasound indications for reimplantation occurred only in 7.3% of cases, and ischemia was diagnosed in 4.9% of patients. Among patients with AAA, who received aortobifemoral Y-grafts, indications reached the level of 91%, and ischemia was established in 45.5% of cases. If we consider patients, who received asymmetric branches (to the iliac artery and to the femoral artery), indications were established in 71% and ischemia was detected in 35.7% of cases. In total, approximately 90% of the patients revealed the risk of ischemia with intensity depending on non-occlusive factor, and it was closely related to the level of average perioperative pressure.

Similarly in the studied group, ischemia occurred in 30% of the patients.

Therefore, it was established that absolute indication for reimplantation of IMA to the prosthesis is a surgical procedure for AAA and iliac arteries with aortobifemoral bypass implantation.

Due to significant elimination of non-occlusive factors in EVAR procedure, we may focus on problem of maintaining patency of IIA orifices. Morphological evaluation of IIA is significantly difficult. Functional evaluation may help. Disturbances in flow hemodynamics occur in majority of IIA.

Equipment manufacturers developed branched stent grafts, with an additional internal iliac branch in the branch of a graft. **Performing the procedure is undoubtedly technically difficult, but it guarantees eliminating the risk of the intestinal and pelvic ischemia.** It is effective and probably the only one method of prevention of the intestinal and pelvic ischemia (37). Other method, such as iliofemoral bypass grafting, is theoretically possible, but practically not preformed due to difficult access and limitation in health requirements for open surgery (38-40). The risk of ischemia in the pelvis and the large colon is frequently assumed in EVAR method. Scientific reports show that such assumptions are not always safe (41). Although the pelvic claudication and sexual functions may be assumed as side effect of the treatment, it is difficult to accept persistent diarrhoea and its consequences, postinflammatory stenosis of the intestine and constipations, ulcerative ischemic inflammation or necrosis and necessity of exteriorization of the intestine (42).

In the studied group, CDD ultrasound evaluation was conducted in reference to all visceral arteries and IIA assuming that the intestinal ischemia may occur in case of occlusion or stenosis of one or two or three visceral arteries – CT, SMA, IMA, and especially IIA. Obstruction of a single artery, even with maintained wide lumen of two remaining vascular trunks, as it was revealed in the control group, may result in ischemia occurrence. It depends on condition of the collateral circulation, rate of the process development and coexistence of other diseases.

Evaluations in the control group show that in case of stenosis and sufficient patency of SMA and IIA, IMA, it may play the most important role in perfusion of the intestines and the lower limbs. It takes place in case of lack of some connections of the collateral circulation.

IMA usually branches into the left colic artery and the superior rectal artery (SRA). SRA constitutes lengthening of IMA towards the rectum, it provides the sigmoid branches and, as a single vessel, it connects the visceral system with systemic network of middle and inferior rectal arteries ensuring two-way flow with maintaining patency of IIA.

The marginal artery of Drummond reveals variable location within the mesenteric edge of the colon, and it receives branches from the ascending branch of the left colic artery and descending branch of the middle colic artery. Within the area of the splenic flexure, it develops collateral network of arcades only in 48% of cases, hypoplasia of connections in 9% of cases and their absence in 43% of cases. The area of the splenic flexure is referred to as Griffiths' point. Maintaining patency of the marginal artery becomes especially important in 20% of cases with absence of the middle colic artery.

Other important branch, the meandering mesenteric artery (of Moskowitz, Gonzales), occurs only in 36% of cases and it connects IMA (before its branching) with the middle colic artery or SMA as the first branch beyond branching from the aorta. The arc of Riolan, which is frequently mentioned in handbooks, develops only in 7-11% of cases with absence or hypoplasia of the ascending branch of the left colic artery – the arc connects the left and the middle colic arteries. Some authors also differentiate the arc depending on location of connections (11).

Analysis of anatomical causes shows the way how unfortunate system of collateral branches and accompanying impairment in IMA patency is favourable to intestinal ischemia: in case of closed flow in IIA or impairment of flow in SMA.

Occlusion of IMA after EVAR procedure may be serious, if there is coexisting SMA stenosis or there are no anatomical connections. It is supported by ultrasound

risk factors depending on systolic velocities and RI (tab. 1).

Degrees of stenosis were assigned to specific ranges in values of the flow parameters in the visceral arteries with stenosis.

Obtained parameters of visceral flows in a studied group remain within similar ranges of values (tab. 2).

Within the whole material of the patients (both groups), VRI values are various.

In case of the patients at no risk, results are close to the results of healthy subjects (reference value: 0.85-1.1∼1.0).

The patients with suspected occlusive ischemia reveal VRI parameters, which are significantly lower than normal, i.e. within the range of 0.3-0.8 [VRI<<1.0 (0.85)].

In cases with suspected non-occlusive ischemia, VRI value is slightly higher or close to 1.0 (VRI > 1.0). For this reason, in case non-occlusive ischemia, another value was introduced, i.e. resistance index (RRI). In case of occlusive ischemia, RRI values are higher or close to 1.0 (RRI > 1.0). In case non-occlusive ischemia, RRI values are lower or close to 1.0 (RRI < 1.0) (tab. 3).

Within a course of a significant stenosis of SMA, we notice increased systolic velocity and decreased peripheral resistance in patients of the risk group. In IMA, velocity reveals normal values, and peripheral resistance is variable and it is not a characteristic value. In the group of the patients, where: VRI < 1.0 and RRI > 1.0, we may predict an occlusive ischemia, but IMA occlusion is its direct cause. This group includes the patients after EVAR procedure.

Therefore, we may assume that using CDD ultrasound evaluation before the surgery, would support not only suspicion of ischemia occurrence, but also predict its clinical form (occlusive/non-occlusive).

Considering all previously listed risk factors, causes for development of the postoperative ischemic colitis may be defined as a group of consecutive adverse events within the perioperative course, related to a specific surgical management in IMA and iliac arteries, at the background of anatomical abnormalities of the visceral arteries, which were existing before and developed after the surgery, which unfavourable effects are disclosed within the course of hypotonia and hypovolemia, influencing the development of disturbance in autoregulation in the visceral bed.

CONCLUSIONS

CDD ultrasound evaluation of the visceral arteries is preoperative evaluation predicting occurrence of ischemia after surgeries of abdominal aortic aneurysms.

A prognostic parameter for an occlusive ischemia, which is established based on CDD ultrasound evaluation, is the velocity ratio of ischemia (VRI) significantly lower than one (<< 1.0), and the secondary resistance ratio of ischemia (RRI) higher than one (≥ 1.0).

A prognostic parameter for non-occlusive ischemia, which is established based on CDD ultrasound evaluation, is resistance ratio of ischemia (RRI) lower than one (≤ 1.0), and the secondary velocity ratio of ischemia (VRI) higher than one (≥ 1.0).

Occlusive ischemia of the colon after surgery of a stent graft implantation into AAA results from covering IMA orifice, which is independent from an operator, and covering the iliac artery orifices with internal branches of a stent graft, which is dependent from an operator.

During classical surgery for AAA repair, both factors of ischemia are acting – an occlusive factor depending on an operator (proceeding with IMA) and non-occlusive factor (hypoxia), which is less dependent on an operator.

Table 1. Ultrasound risk factors in a control group.

Parameter		CT	SMA	IMA	IIA
SV	< 60%	162-217	160-211	50-177	62-178
	60-80%	213-254	213-378	201-221	182-238
	> 80%	–	–	54-350	–
RI		> 0.7 (0.68-0.91)	> 0.8 (0.70-0.93)	< 0.8 (0.61-0.92)	> 0.8 (0.78-0.98)
Stenosis		> 60%	> 60%	100%	> 60%

Table 2. Obtained ranges of the key parameters in a studied group.

Parameter		CT	SMA	IMA	IIA
SV	< 60%	122-325	89-287	89-179	34-165
	60-80%	–	–	199 <	165-214
RI		0.66-0.88	0.82-0.91	0.75-0.95	0.78-0.96

Table 3. Distribution of ratios of ischemia in both groups.

Ratio	Healthy subjects	Occlusive ischemia	Non-occlusive ischemia
VRI	VRI < 1.0 (0.85-1.1)	VRI << 1.0 (0.3-0.8)	VRI ≥ 1.0
RRI	variable	RRI ≥ 1.0	RRI ≤ 1.0

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