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Особенности выполнения резекции позвоночного столба по поводу ригидных кифотических и кифосколиотических деформаций грудопоясничного отдела позвоночника различного генеза: мультицентровое ретроспективное наблюдательное когортное исследование

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АННОТАЦИЯ

Обоснование. Резекция позвоночного столба (vertebral column resection, VCR) как вид остеотомии позвоночника характеризуется максимальными возможностями трёхмерной коррекции различного генеза: врождённого, посттуберкулёзного, ятрогенного (после иных вмешательств на позвоночнике), дегенеративного, а также при спондилоптозе позвонка, обусловленном болезнью Кюммеля, и при первичных и метастатических опухолевых поражениях позвоночника. К настоящему моменту применение VCR вышло далеко за рамки своего первоначального предназначения.

Цель. Сравнить особенности выполнения VCR по поводу ригидных деформаций различной этиологии, а также менеджмента эритроцитарных препаратов крови в периоперационном периоде.

Материалы и методы. Мультицентровое ретроспективное наблюдательное когортное исследование проведено на основе данных 53 взрослых (≥18 лет) пациентов с кифотическими и кифосколиотическими деформациями грудного и поясничного отдела позвоночника, разделённых на 4 группы сравнения по генезу деформации: аномалии развития позвоночника, травматический генез, дегенеративный либо идиопатический кифосколиоз, новообразования тел позвонков.

Результаты. При выполнении VCR по поводу новообразований позвоночника длительность операции оказалась выше, чем при VCR по поводу высокоэнергетических «взрывных» компрессионных переломов тел позвонков и сколиотических деформаций IV степени (p <0,05). Дополнительно эта группа характеризуется в среднем наиболее краниальным значением уровня остеотомии среди групп пациентов, участвовавших в исследовании. VCR по поводу идиопатических сколиотических деформаций отличается большим объёмом интраоперационной кровопотери, чем иные рассмотренные в исследовании нозологии (различия также носят статистически значимый характер). Кроме того, у пациентов-мужчин этой группы уровень гемоглобина на 1-е сут после вмешательства статистически значимо ниже, чем у пациентов, которым VCR выполняли по поводу компрессионных переломов тел позвонков, либо деформации, вызванной аномалией развития позвонка. При VCR по поводу «взрывных» компрессионных переломов тел позвонков протяжённость фиксации меньше, чем при аналогичном вмешательстве по поводу аномалий развития и деформаций постоперационного генеза, а также идиопатического сколиоза IV степени (p <0,05). При выполнении VCR по поводу идиопатического сколиоза IV степени требуется больший (p <0,05) объём реинфузированной аутокрови, чем при вмешательстве по поводу острой травматической патологии («взрывных» компрессионных переломах тел позвонков).

Заключение. Универсальность клинических задач, при которых может быть выполнена резекция позвоночного столба по методике VCR, обусловливает и значительную гетерогенность групп пациентов, которым проводится такое лечение. Знание особенностей выполнения вмешательств по поводу ригидных кифотических и кифосколиотических деформаций различного генеза имеет ценность в вертеброгической практике.

Ключевые слова: резекция позвоночного столба; интраоперационная потеря крови; гемоглобин; хирургия позвоночника; травма позвоночного столба; новообразования позвоночного столба; компрессионный перелом; кифосколиотическая деформация; кифотическая деформация.

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Aspects of vertebral column resection in patients with rigid kyphotic and kyphoscoliotic deformities of different genesis of the thoracolumbar spine: multicenter retrospective observational cohort study

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ABSTRACT

BACKGROUND: Vertebral column resection (VCR) as a type of spinal osteotomy is characterized by maximum possibilities of three-dimensional correction of various etiologies: congenital, post-tuberculous, iatrogenic (after other interventions on the spine), degenerative, and vertebral spondyloptosis caused by Kümmel's disease, and primary, and metastatic tumor lesions of the spine. Nowadays, the use of single-level VCR is far beyond its initial purpose.

OBJECTIVE: The study aimed to compare features of VCR for rigid deformities of various etiologies and management of erythrocyte blood products in the perioperative period.

MATERIALS AND METHODS: A multicenter retrospective observational cohort study analyzed data from 53 adult (aged ⩾18 years) patients with kyphotic and kyphoscoliotic deformities of the thoracic and lumbar spine, distributed into four comparison groups according to the deformity genesis, namely, impaired spinal development, traumatic genesis, degenerative or idiopathic, and neoplasms of the vertebral bodies. The characteristics of VCR in these patients were compared.

RESULTS: The surgery duration was longer in VCR for spinal neoplasms (p <0.05) than for high-energy burst compression fractures of vertebral bodies and scoliotic deformities (grade IV). On average, this group also had the most cranial osteotomy level among the study groups. VCR for idiopathic scoliotic deformities is characterized by a larger intraoperative blood loss volume than other nosologies, and the differences were statistically significant. In male patients of this group, the hemoglobin level on day 1 after surgery was statistically significantly lower than in those who underwent VCR for compression fractures of the vertebral bodies or impaired vertebral development. During resection of the vertebral column for burst compression fractures of the vertebral bodies, the fixation length was less (p <0.05), with a similar intervention for developmental anomalies, deformities of postoperative genesis, and grade IV idiopathic scoliosis. VCR for grade IV idiopathic scoliosis requires a larger (p <0.05) volume of the reinfused autologous blood than for intervention for acute traumatic pathologies (burst compression fractures of the vertebral bodies).

CONCLUSION: The versatility of clinical tasks for which resection of the spinal column can be performed using the VCR technique also determines the significant heterogeneity of the patients who undergo such treatment. Knowledge of the interventions in various nosologies is very useful in vertebrological practice.

Keywords: vertebral column resection; intraoperational blood loss; hemoglobin; spine surgery; spine trauma; spine neoplasm; compression fracture; kyphoscoliotic deformity; kyphotic deformity.

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BACKGROUND

Vertebral column resection (VCR) is a type of three-column spinal osteotomy, accompanied by the total removal of one or more vertebrae at the deformity apex, followed by spatial anatomical reconstruction of the spine, and characterized by the maximum possibilities of three-dimensional correction. Since the proposal of the MacLennan method in 1922 [1], attempts have been made to treat deformities of various origins, namely, congenital, post-tuberculous [2–7], iatrogenic (after other interventions on the spine), and degenerative [8, 9], L_V vertebra spondyloptosis [10], due to Kümmell's disease [11, 12], and in primary and metastatic tumor lesions of the spine [13–15]. To date, VCR is used far beyond its original purpose. Numerous studies are available in the literature; however, they focused on a highly specialized subject, namely, the use of VCR in certain nosologies. Literature reviews are compiled based on available articles; as a rule, they do not follow a single methodology for collecting data and had differences in measurement units used. Thus, comparison of such results is difficult for both clinicians and doctors involved in scientific activities.

This study represents one of the first attempts to generalize VCR experience in adult patients based on the results of various vertebrological centers in the Russian Federation, which will enable the formation of an interdisciplinary concept and clarify its indications and contraindications. As a first step, we consider it appropriate to compare surgical interventions for scoliotic, kyphotic, and kyphoscoliotic deformities with a Cobb angle of >40° ("target group" of patients) for nosological groups that a vertebrologist may deal with in practice and the required amount of erythrocyte blood products of such interventions perioperatively.

This study aimed to compare parameters of spinal column resection for rigid deformities of various etiologies and the management of erythrocyte blood products perioperatively.

MATERIALS AND METHODS

Study design

A multicenter retrospective observational cohort study design was employed.

Eligibility criteria

Inclusion criteria

- Rigid kyphotic or kyphoscoliotic deformity of the thoracic or lumbar spine with a Cobb angle in the kyphotic plane of >50°
- VCR surgery with transpedicular fixation from the dorsal approach
- Congenital spinal anomalies causing the deformity described, or vertebrological intervention on the posterior column of the spine, resulting in its formation (group 1)
- High-energy (traumatic) compression fractures of the vertebral body beyond the acute period of trauma, at least 6 months (group 2)
- Hospitalization and surgical treatment performed beyond the chemotherapy and radiation therapy periods, in agreement with the oncologist managing the patient (group 4).

Exclusion criteria:

- VCR from the ventral access or two accesses
- VCR at more than 1 level
- Simultaneous vertebrotomies of a smaller volume (PSO, SPO, and others)
- Use of posterior fixation other than transpedicular one, including hybrid fixation

Terms and conditions

The study was based on data from 53 adult patients (aged ⩾18 years) with kyphotic and kyphoscoliotic deformities of the thoracic and lumbar spine, who received VCR surgical treatment between 2008 and 2020 at N.N. Priorov National Medical Research Center of Traumatology and Orthopedics (Moscow), R.R. Vreden Russian Scientific Research Institute of Traumatology and Orthopedics (St. Petersburg), and Privolzhsky Research Medical University (Nizhny Novgorod).

Study duration

The study was conducted during the period from 2021 to 2022 and retrospectively analyzed data from patients who were surgically treated for kyphotic and kyphoscoliotic deformities of the thoracic and lumbar spine using the VCR technique between 2008 and 2020. The observation period was limited by the duration of hospitalization; given the retrospective study design, the registration of the data collected was accepted as a surrogate ("soft") endpoint.

Description of the medical intervention

All the included patients underwent a single-level spinal column resection according to the generally accepted technique, which included the creation of a surgical approach, installation of transpedicular screws, and temporary rods, resection of the posterior supporting column of the vertebra, resection of the middle, and anterior supporting columns of the vertebra, apposition of the cranial, and caudal fragments of the spine, replacement of rods for permanent ones, final fixation, and closure of the surgical wound. The surgery was performed under combined endotracheal anesthesia under intraoperative neuromonitoring. Intraoperative reinfusion of autologous blood using a cell-saver apparatus was performed.

Research outcomes

A surrogate endpoint, corresponding to the determination of hemoglobin concentration on day 1 after the intervention,

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was adopted as the study outcome, given its retrospective nature. Information about other indicators used in this study was already available at the endpoint.

Methods of outcome registration

The following parameters were measured and analyzed:

- Demographic indicators such as distribution by sex and age
- Duration of the intervention
- Intraoperative blood loss
- Amount of blood reinfused during the intervention
- Osteotomy level (calculations were taken into account as 1–12 for thoracic vertebrae from Th_I to ThX_{II}, respectively; 13–17 for lumbar vertebrae from L_I to L_V, respectively)
- Fixation length (measured as the number of fixed spinal motion segments)
- Hemoglobin concentration (g/L) for men and women separately before the surgery (preoperative level) and on day 1 after it (postoperative level)

Subgroup analysis

Patients were distributed into four main groups according to the nature of the underlying disease or injury that caused the onset and growth of kyphotic/kyphoscoliotic deformity. Table 1 presents the characteristics of the groups that were used as the basis for the distribution.

In group 4, the types of neoplasms of the vertebral bodies were distributed as follows:

- Tumor, histologically unspecified lesion of the vertebral body (at the time of data collection, the biopsy material was being processed), *n*=3; damage levels Th_{III}, Th_{XII}, and L_I
- Chondrosarcoma of Th_{VI}, *n*=1
- Chondrosarcoma, ICD-O code 9250/1, degree 2, grade 2, *n*=1
- Giant cell tumor (osteoclastoma) of Th_X, *n*=1
- Giant cell tumor (osteoclastoma) of Th_{III} (aggressive type), ICD-O code 9250/1, *n*=1
- Breast carcinoma of L_I (metastasis, luminal subtype A), *n*=1
- Clear cell renal cell carcinoma of Th_{VII} (metastasis), *n*=1

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics (calculated mean value of the parameter, standard deviation, and minimum and maximum values) were used for the general presentation of data. The Mann–Whitney *U*-test was used to determine differences in parameters between each of the two groups. The nature of the differences (high or low value of the parameter in the compared groups) was determined only with confirmed (p <0.05) statistical significance. This nonparametric criterion was chosen based on the differences in the number of patients in the groups analyzed and the insufficiency of the sample size (*n*=21 in the largest group) for parametric tests. *P*=0.05 was taken as the threshold level of asymptotic significance.

RESULTS

Study participants

The study involved 53 patients, which included 22 (41.5%) men and 31 (58.5%) women. The mean age of the patients was 49.17±15.82 years. Table 2 presents the descriptive data on the main studied parameters.

When searching for differences between groups in the pairwise comparison using the Mann–Whitney *U*-test, the results presented in Table 3A–D were obtained.

Tables 2 and 3 presented the following results:

- The surgical duration in group 4 (VCR for neoplasms of the vertebral bodies) was statistically significantly different from that in groups 2 (p=0.035) and 3 (p=0.039) (VCR for injuries and rigid scoliotic deformities of the spine, respectively) upwards.
- The intraoperative blood loss volume in group 3 (VCR for degenerative/idiopathic scoliosis) was statistically significantly different from that in all other groups in the upward direction (p=0.014 compared with group 1, p <0.001 compared with group 2, and p=0.039 compared with group 4).
- In the male patients of group 3, the hemoglobin concentration on day 1 after the intervention differed downward statistically significantly from those in groups 1 (p=0.016) and 2 (p=0.036), whereas before

Table 1. Distribution of patients into four groups in accordance with the main nosology

Conventional name of the group	Number of patients, *n*	Deformity genesis
1	8	Congenital (developmental anomalies)
2	21	Traumatic (high-energy compression fractures of the vertebral bodies)
3	15	Adult degenerative or idiopathic kyphoscoliosis
4	9	Oncological (neoplasms of the vertebral bodies, associated metastases, and compression fractures)

Table 2. Descriptive data of the main studied parameters

Group	Number, *n*	Minimum	Maximum	Average	Standard deviation
Intervention duration, min					
1	8	210	660	360,00	155,47
2	21	210	580	303,33	90,35
3	15	165	420	299,33	70,93
4	9	155	600	400,00	137,55
Intraoperative blood loss, mL					
1	8	400	2500	1131,25	763,89
2	21	300	2900	840,48	602,62
3	15	700	8100	2900,60	2200,38
4	9	200	2320	946,67	732,87
Volume of blood reinfused intraoperatively, mL					
1	8	0	900	307,25	332,83
2	21	0	744	109,19	207,15
3	15	0	2226	732,13	667,26
4	9	0	0	0	–
Osteotomy level					
1	8	6	16	11,25	4,43
2	21	3	15	10,81	3,40
3	15	6	16	13,87	3,93
4	9	1	13	7,11	4,40
Length of fixation (in spinal motion segments)					
1	8	3	14	8,25	3,69
2	21	5	10	5,76	1,51
3	15	2	17	8,87	4,58
4	9	5	9	6,33	1,32
Peripheral blood hemoglobin before surgery, g/L					
Men					
1	5	117	167	139,80	19,15
2	11	112	150	131,55	13,83
3	4	119	136	127,50	6,95
4	2	128	140	134,00	8,49
Women					
1	3	125	166	145,67	20,50
2	10	103	156	129,00	18,74
3	11	100	150	129,55	13,74
4	7	113	155	127,57	15,15
Peripheral blood hemoglobin on day 1 after surgery, g/L					
Men					
1	5	104	139	118,40	12,90
2	11	92	129	109,18	12,46
3	4	88	102	95,75	7,32
4	2	97	126	111,50	20,51
Women					
1	3	105	126	116,00	10,54
2	10	74	126	99,80	14,99
3	11	88	140	111,18	18,87
4	7	87	143	110,71	18,59

Note. Means and standard deviations are rounded to two decimal places.

Table 3. Asymptotic significance of differences (*p*) between groups when compared using the Mann–Whitney U-test

A

Surgical duration →	Group	1	2	3	4	Intraoperative blood loss ←
	1	–	0,340	**0,014**	0,592	
	2	0,509	–	**<0,001**	0,982	
	3	0,456	0,680	–	**0,003**	
	4	0,531	**0,035**	**0,039**	–	

B

Fixation length →	Group	1	2	3	4	Osteotomy level ←
	1	–	0,554	0,106	0,066	
	2	**0,016**	–	**0,001**	**0,026**	
	3	0,770	**0,013**	–	0,001	
	4	0,238	0,093	0,182	–	

C

Hemoglobin concentration before surgery, men →	Group	1	2	3	4	Hemoglobin concentration on day 1 after surgery, men ←
	1	–	0,192	**0,016**	0,857	
	2	0,461	–	**0,036**	0,843	
	3	0,268	0,695	–	0,348	
	4	0,845	0,921	0,240	–	

D

Hemoglobin concentration before surgery, women →	Group	1	2	3	4	Hemoglobin concentration on day 1 after surgery, women ←
	1	–	0,107	0,697	0,419	
	2	0,176	–	0,192	0,282	
	3	0,243	0,860	–	0,964	
	4	0,137	0,883	0,717	–	

E

Reinfusion volume →	Group	1	2	3
	1	–		
	2	0,073	–	
	3	0,111	**0,001**	–

Note. Statistically significant (p <0.05) differences are shown in bold. The reinfusion volume was not compared with group 4 (Table 3, D) because reinfusion was not used in this group. Values are rounded to three decimal places.

the intervention, these differences were not detected (Table 3C).

- In female patients, differences in hemoglobin levels were not detected either before or on day 1 after the intervention (p >0.05; Table 3D).
- The length of hardware fixation in group 2 (VCR for high-energy traumatic compression fracture of the vertebral body) was statistically significantly shorter than that in group 1 (p=0.016) and group 3 (p=0.013) (VCR for developmental anomalies and deformities of postoperative genesis and idiopathic scoliosis, respectively).
- Osteotomy levels differed statistically significantly between groups 2 and 3 (p=0.001), between groups 2 and 4 (p=0.026), and between groups 3 and 4 (p=0.001). The differences between groups 4 and 1 cannot be currently considered statistically significant (p=0.066); however, they can potentially be proven in the future with an increased sample size. Group 4 (VCR for neoplasms of the vertebral bodies) was characterized, on average, by the lowest level of osteotomy among all the studied groups, which corresponds to the most cranial location of the altered vertebrae within the thoracic and lumbar regions.
- The reinfusion volume was statistically significantly different in groups 2 and 3 (VCR for injuries and degenerative/idiopathic scoliosis, respectively; p=0.001), whereas group 3 required the highest volume of autologous blood.

In general, the VCR outcomes in *group 1* (deformities caused by developmental anomalies and postoperative deformities) were not statistically significantly different when compared with other groups in all parameters studied.

Group 2 (high-energy compression fracture of the thoracolumbar spine beyond the acute phase) was characterized by the shortest fixation length (average 5.76 levels), which may be due to the absence or minimal disturbance of the sagittal balance in these patients, and its correction does not require a significant hardware length.

Group 3 (scoliotic deformities of degenerative–dystrophic and idiopathic genesis) was characterized by the largest/maximum intraoperative blood loss (on average, 2900.60 mL, which is 2–3 times higher than this indicator for other groups). A large intraoperative blood loss causes increased requirements for reinfusion (average 732.13 mL for this group) and low hemoglobin concentration on day 1 after the intervention (average 95.75 g/L in men and 99.80 g/L in women). The fixation length in group 3 (on average 8.87 levels of the spine) exceeded that of all other groups, which was due to the need for deformity correction simultaneously in two planes (frontal and sagittal), which increased the surgical intervention requirement and, consequently, blood loss. The need for reinfusion also increased.

In *group 4* (VCR to correct deformities caused by tumor lesions of the vertebrae), interventions were most often performed in the mid-thoracic region at the Th_{VII}–Th_{VIII} level. This situation is possibly caused by the unpredictable (at this stage) development (location) of metastatic foci and other neoplasms in the vertebral bodies. Moreover, the "large caudality" of the average levels in other groups (Th_{XI}–Th_{XII} vertebrae in group 1, Th_{X}–Th_{XI} in group 2, and L_{I}–L_{II} in group 3) may be associated with the following:

- Patient composition for group 1 (in terms of the location of the altered vertebrae)
- Specificity of the thoracolumbar transition segment as a zone of damage for group 2 [the probability of a compression fracture of the upper and middle thoracic vertebrae in the case of injury was slightly lower than that of the underlying (lower thoracic and lumbar ones)]
- For group 3, the choice of the osteotomy level in accordance with the actual nature of the deformities in the included patients

When compared between groups, statistically significant differences in the osteotomy level were found between groups 4 and 2 (kyphotic deformities due to chronic vertebral compression fractures; p=0.035) and group 3 (VCR due to rigid scoliotic deformities; p=0.039).

On average, the duration of the onco-orthopedic intervention was the highest in group 4 when compared with the rest of the groups, which can be due to increased requirements for the technique due to the principles of ablastic surgery.

Adverse events

No adverse events were reported during the study.

DISCUSSION

Summary of the main research outcome

When performing VCR for spinal neoplasms, the surgical duration was statistically significantly higher than for VCR for high-energy burst compression fractures of the vertebral bodies and grade IV scoliotic deformities. This group was also characterized, on average, by the most cranial osteotomy level among the studied patients.

VCR for idiopathic scoliotic deformities is characterized by a larger intraoperative blood loss volume than other nosologies considered in the study, showing statistically significant differences. Moreover, in male patients of this group, the hemoglobin level on day 1 after the intervention was statistically significantly lower than that in those who underwent VCR for compression fractures of the vertebral bodies or deformity caused by a vertebral developmental anomaly.

In the spinal column resection for burst compression fractures of the vertebral bodies, the extent of fixation was statistically significantly less than with a similar intervention for developmental anomalies, deformities of postoperative genesis, and grade IV idiopathic scoliosis.

VCR for grade IV idiopathic scoliosis required statistically significantly larger amounts of reinfused autologous blood than the intervention for acute traumatic pathology (burst compression fractures of the vertebral bodies).

Discussion of the main research results

Even the baseline information about blood management in VCR is currently extremely poorly covered. We did not find a single publication in the literature that described the hemoglobin level in peripheral blood before and after (on day 1) VCR, and data about other parameters considered, except for the surgical duration and intraoperative blood loss, were not given in all studies. Comprehensive coverage of the achieved correction from a radiological and neurological point of view is common, whereas blood management and comparison of the perioperative features of VCR in various nosologies remain beyond the main focus of vertebrological cogitations, despite their obvious relevance for clinicians.

Developmental anomalies (Group 1)

The analysis of VCR parameters for patients with abnormal spinal development is conceptually complex because of the diversity of the anomalies and, accordingly, the required extent of surgical intervention. Thus, we consider it appropriate to focus on the analysis of studies on developmental anomalies, where only one vertebra is affected, which should be resected.

The absolute number of publications describing the use of VCR for impaired spinal column development (resulting in kyphotic, kyphoscoliotic, or scoliotic deformities) is focused on the treatment of children and adolescents (aged 0–17 years). Data on the treatment of adults (aged ≥18 years) are extremely limited. The study conducted by Liu et al. is an example of high-quality work related to the results of VCR for congenital scoliosis caused by developmental anomalies [16]. Despite the emphasis on radiological parameters, in addition to the main findings, the authors also provide some "atypical" data that are rarely found in publications. Thus, intraoperative blood loss among 24 patients was

1754±657.3 mL, which is slightly higher than our findings (1131.25±763.89 mL), and the number of pedicle screws was 14.3±1.6 (range 12–16). As a disadvantage for a full-fledged comparison, determining the number of fixed levels by the number of screws is impossible because there can be from 0–2 screws at a certain level.

Compression traumatic fractures (Group 2)

Given its complexity, VCR is not the method of choice for deformity correction in compression (including burst) fractures of the thoracic and lumbar spine, even beyond the acute phase of injury. The priority in such injuries is the most rapid and technically simple achievement of stability in the damaged segment while eliminating the compression threat to neural structures (i.e., spinal cord, roots, and nerves). Such patients do not have sagittal balance disorders developing for a long time; therefore, under such conditions, the minimum necessary fixation, including five levels, proves itself (two levels cranial to the damaged vertebra + the damaged vertebra itself + 2 levels distal to it). This reason explains the smallest fixation length in all groups (5.76±1.51 levels; Table 2), although significant differences were found only in group 1 (planned interventions for developmental anomalies of the spine, resulting in its deformity).

The literature provides data on the results of three-column reconstruction of the spine through the posterior approach, which is very similar to VCR. Hamzaoglu et al. [17] summarized their experience of performing VCR from the dorsal approach in 51 adult patients with traumatic pathologies such as burst compression fractures of the vertebral bodies. The average duration of the intervention was 434 (270–535) min, which was on average higher than our data (303.33±90.35 min). The average intraoperative blood loss was 520 (360–1100) mL, which was somewhat lower than our results (840.48±602.62 mL) but was generally comparable to their results. The authors emphasized the importance of the combined use of hemostatic measures such as intraoperative administration of tranexamic acid, maintenance of optimal blood pressure during the intervention, widespread use of thermocoagulation of small vessels, and use of high-speed burs. The study limitation was the fact that in 3 of 51 (5.88%) patients, osteotomy was performed at two levels; therefore, we cannot establish complete methodological compliance. However, we can form a comparative impression of the intervention results.

Degenerative and idiopathic kyphoscoliosis (Group 3)

Zhang et al. [18] presented the evaluation results of the efficiency of VCR in 12 patients with grade IV rigid idiopathic scoliosis, which revealed that VCR performed for this nosology (mean angle of deformity before and after the intervention were 108.91°±16.56° and 56.49°±18.82°, respectively) was characterized by an average blood loss of 1333.33±574.19 mL and surgical duration of 326.67±27.91 min. Thus, the surgical duration was longer than that recorded in our study; however, the intraoperative blood loss volume was lower. In the study, the average number of fixation levels was 11.33±2.27, which was more than the average value obtained in our study with 8.87±4.58.

Zhou et al. can also be considered [19] to have certain limitations, as their study focused, among other things, on performing VCR in patients with rigid scoliotic deformities. Of 22 patients, idiopathic scoliosis was registered in 16 patients, and neuromuscular scoliosis was detected in 6 patients. The authors report an average surgical duration of 539.5±38.0 min, with an intraoperative blood loss volume of 1895.5±566.7 mL, which is slightly lower than our intraoperative blood loss of 2900.60±2200.38 mL, but higher than the average surgical duration recorded in our study (the lowest of 299.33±70.93 min in group 3, and the highest of 400.00±137.55 min in group 4). A significant limitation for the analysis is the authors' consideration of a two-approach one-stage VCR in contrast to the one-approach VCR investigated in our study.

Oncological nosologies (Group 4)

Information on the use of VCR in the field of onco-orthopedics, which is not related to the description of individual clinical cases, is scarce in the literature. Jandial et al. [15] studied the results of spinal column resection in the lumbar region from the posterior mono-approach performed for a metastatic lesion. A total of 11 adult patients (6 men and 5 women) were included in the study. The distribution by nosology of primary neoplasm among patients was as follows: two patients with neoplasm of the prostate, two patients with that of the kidney, one with lung neoplasm, one with neuroendocrine tumor, one with breast cancer, one with plasmacytoma, one with alveolar rhabdomyosarcoma, and one with thyroid gland neoplasm. The average intraoperative blood loss was 1618 (900–4000) mL, which was significantly higher than our results of 946.67 (200–2320) mL. However, in our patients, the osteotomy was performed mainly in the thoracic spine (L_I was the only level of the lumbar spine in our study). A smaller blood loss volume with similar principles of intervention can be due to the smaller size of the thoracic vertebrae and the smaller volume (and wound area) of the adjacent muscle masses, which impose appropriate hemostatic requirements. The authors provide data on intraoperative blood loss for each of the 11 patients, indicating histological data; however, due to the diversity of the histological nature of neoplasms, each type requiring VCR is rare. Thus, the analysis of possible relationships between the histological type of neoplasm and intraoperative blood loss is currently premature because of data paucity.

When comparing intraoperative blood loss with that in other patients, our study revealed (Table 3A) statistically significant (p=0.003) differences between this group and

group 3, corresponding to patients with rigid scoliotic deformities; thus, this indicator was higher in group 3 than in group 4. This can be due to a shorter fixation length (8.87±4.58 levels in group 3 and 6.33±1.32 levels in group 4), which implies a longer approach for the scoliotic deformity correction, more time for its creation and closure, and therefore an inevitable large blood loss during the intervention.

Jandial et al. [15] also reported an average surgical duration of 6.6 h (396 min), which ranged from 4.5 to 9 h (270–540 min). Our results generally agree with this time interval, in which the average value in our study was 400 (155–600) min.

In an article analyzing VCR complications in 40 patients with vertebral body neoplasms, Fan et al. [13] also provided some information that is of interest from the point of view of blood management, that is, according to their data, the median intraoperative blood loss volume was 2400 (600–11,000) mL, the intervention duration was 305.8±78.2 (135 to 470) min, and the transfusion volume of erythrocyte blood components was 2600 (0–26200) mL which is generally less than our results in terms of the intervention duration, but higher than other parameters. Moreover, in 4 of 40 (10%) patients, two adjacent vertebrae (not 1 vertebra) were removed; therefore, we cannot fully compare the results of this work and our study.

Interestingly, the authors [13] registered 75% (30/40) of neoplasms in the thoracic spine and 25% (10/40) in the lumbar spine. The predominant localization in the thoracic spine corresponds generally to our results. In the study by Dreimann et al. [14], which focused on the treatment of 11 patients with metastatic spinal cord compression, all (100%) patients had a metastatic lesion of the thoracic spine, which confirms an increased "tendency" to metastasis in this region compared with the lumbar spine. A thoracic localization may be of some importance for estimating the intraoperative blood loss volume and planning for VCR replacement therapy.

Study limitations

given the lack of randomization in this observational study, confounding factors could not be controlled. The study was also limited by its retrospective design.

CONCLUSION

The versatility of clinical tasks for which spinal column resection can be performed using the VCR technique also determines the significant heterogeneity of patients who receive such treatment. In accordance with nosologies, various requirements are imposed on surgical interventions, namely, ablasticity, spinal stabilization rate, optimal biomechanics of a fixed spine, and others. Knowledge of the features of interventions in various nosologies is very useful in vertebrological practice.

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