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Application Of Three-Dimensional Reconstruction For Planning Complex Surgical Interventions In Newborns

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ABSTRACT

In modern medicine three-dimensional reconstruction methods are more and more widely used in various fields of surgery. They are of particular relevance when planning and performing complex surgical interventions in newborns, since any error in the preoperative assessment of anatomical structures can affect the outcome of treatment.

This study analyses the possibilities of three-dimensional reconstruction in planning operations for congenital malformations and evaluates the effectiveness of this approach in improving diagnostic accuracy and reducing surgical time.

Keywords: *three-dimensional reconstruction, newborns, surgical planning, congenital malformations, computed tomography, magnetic resonance imaging, diagnostic accuracy, surgical outcomes.*

1. INTRODUCTION

Surgical treatment of newborns with congenital malformations requires the most accurate diagnosis and detailed anatomical visualization of the pathological focus. Errors at the planning stage of surgery can lead to serious complications, since the size of anatomical structures in newborns is extremely small and the functional reserves of the organism are limited.

Over the last two decades, three-dimensional reconstruction methods based on computerized or magnetic resonance tomography data have appeared and are actively developing. These methods make it possible to visualize complex anatomical structures in detail and predict expected changes during surgical intervention, which helps to reduce intraoperative risks [10].

The peculiarity of 3D reconstruction in newborns is the need to combine high spatial resolution with the lowest possible radiation exposure, which is especially important in the presence of severe comorbidities. In addition, it is necessary to take into account the technical and physiological features of young patients, because when performing computed tomography it

is important to ensure immobility of the child, and when using magnetic resonance imaging there is a need for special equipment and a fairly long study time [7].

3D modeling technologies provide surgeons with more accurate incision planning and understanding of anatomy, especially in the presence of complex congenital anomalies such as congenital heart disease, skeletal anomalies or rare co-morbidities [2].

The aim of this study was to evaluate the clinical and diagnostic efficacy of 3D reconstruction for planning complex surgical interventions in neonates.

To achieve this goal, we analyzed the groups of patients who underwent preoperative 3D reconstruction and compared the results of surgical interventions and the incidence of intraoperative complications with the group in which such an approach was not used.

2. MATERIALS AND METHODS OF THE STUDY

The study was conducted in a multidisciplinary centre specializing in the provision of high-tech care to newborns with congenital malformations. The sample included patients aged from the first day of life to one month of age who were diagnosed with complex malformations requiring surgical correction.

The analysis was based on data collected over a period of three years to ensure representativeness and a relatively uniform distribution of pathologies. The medical records of 40 newborns were reviewed, 20 of whom had preoperative three-dimensional reconstruction (group A), and the remaining 20 patients (group B) did not have such an approach.

Computed tomography (CT) was used as the main diagnostic technique, and in cases where the child was assigned a magnetic resonance imaging (MRI) protocol for some clinical reasons, reconstructions were performed based on MRI data [10].

A licensed software package (Mimics Innovation Suite, Materialise) was used for 3D reconstruction, which allows the selection of anatomical objects of interest, creation of volumetric models and exporting them for further analysis and planning. Preparation for the study included the use of sedation to minimize the child's movements. The radiation dose during CT was optimized by using low-dose protocols and reconstruction algorithms specifically adapted for newborns.

Before the operation, a multidisciplinary consilium was held, at which surgeons together with radiologists and anaesthesiologists discussed the results of reconstruction, determined the scope of intervention and the specifics of surgical access. The study evaluated the time spent on surgical intervention, the amount of blood loss, the incidence of intra- and postoperative complications, and the need to change the initial surgical plan during the course of the operation.

The methods of descriptive statistics were used for statistical analysis; the comparison of average indices was performed using Student's t-criterion in case of normal distribution and Mann-Whitney criterion in case of deviation from normality.

The software package SPSS Statistics (version 26.0, IBM) was used; the level of statistical significance was assumed to be $p < 0.05$.

3. RESULTS AND DISCUSSION

The collected material allowed us to trace the correlation between the use of preoperative 3D reconstruction and surgical treatment efficacy parameters.

Table 1 is presented to describe the clinical characteristics of patients in both groups. The average age of the newborns was 12 days, but the variation ranged from 2 to 28 days due to the different timing of pathology detection. Birth weight ranged from 1800 to 4400 g, and the mean values in groups A and B were not statistically different. The sex distribution was close to uniform. Most patients had combined pathological conditions such as respiratory and metabolic disorders, which is typical for severe congenital malformations.

Table 1. Clinical characteristics of patients

Parameter	Group A (n=20)	Group B	p-value
Mean age (days)	13,2 ± 6,1	11,7 ± 5,8	0,32
Mean body weight (g)	3100 ± 400	2980 ± 350	0,28
Sex (M/W), number	11/9	10/10	0,68
Associated pathologies (%)	70	65	0,55

There were no differences in demographic characteristics and severity of somatic status between the groups. The main differences were found when assessing the effectiveness of the treatment.

The time spent on surgery was an important indicator for assessing the success of surgical intervention. With the use of three-dimensional reconstruction technique, access planning and tactics were significantly simplified [4]. Surgeons received a detailed spatial picture of the abnormal area and healthy surrounding structures, which allowed them to plan the incision as accurately as possible and choose the optimal sequence of manipulations. In group A, the average duration of surgery was 140 minutes, and in group B - 180 minutes. The analysis showed a statistically significant difference ($p < 0.05$).

Graph 1 shows the distribution of patients in both groups according to the duration of surgery. The graph shows that in group A the majority of operations were between 120 and 160 minutes, whereas in group B operations often exceeded 180 minutes.

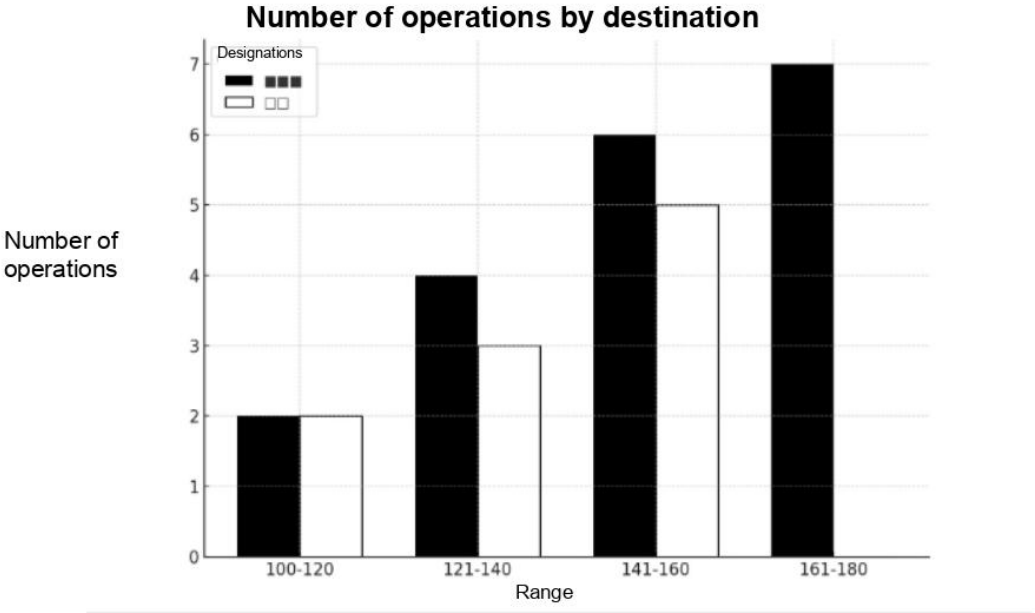

Figure 1. Distribution of surgery duration in groups A and B

The index of intraoperative blood loss deserves special attention. The average volume of blood loss in group A patients did not exceed 40 ml, whereas in group B this value reached 60 ml and more. Reduced blood loss may be due to better orientation of surgeons in pathology and fewer unavoidable 'diagnostic' manipulations [6]. Statistical tests confirmed that the difference in blood loss rates between groups was significant ($p < 0.05$).

Table 2 summarizes the duration of surgery, blood loss and percentage of intraoperative complications, including the need to widen the incision, switch to more invasive techniques and the occurrence of unforeseen ruptures of vascular structures.

Table 2. Comparison of operative parameters in patients of both groups

Indicator	Group A (n=20)	Group B (n=20)	p-value
Average operation duration (min)	140 ± 25	180 ± 30	< 0,05
Average blood loss (ml)	35 ± 10	58 ± 15	< 0,05
Intraoperative complications (%)	10	25	< 0,05

The differences in intraoperative complications were significant, as an accurate understanding of the internal anatomy in patients with 3D reconstruction allowed surgeons to anticipate potentially dangerous areas and adjust the scope of intervention.

Another important criterion for evaluation was the rate of the need to change the original surgical plan during surgery. In Group A, only two cases required an emergency change of technique or expansion of the operative field. In group B, such situations occurred in five operations. Although this difference was not statistically significant ($p=0.08$), it indicates that preoperative modeling provides a more detailed picture of pathology and reduces the uncertainty factor during the actual intervention.

The results of anesthesiological support deserve special mention. Since the average duration of operations in group A was shorter, the total dose of anaesthetics administered decreased, which had a favourable effect on the stability of haemodynamic parameters of the newborn. An analysis of anaesthesia charts showed that the average blood pressure and heart rate during surgery in group A patients showed less fluctuations than in group B, although the difference in most cases did not reach a statistically significant level.

An important component of this study is related to the analysis of the radiation exposure of the child. The technique of low-dose computed tomography, specially developed for newborns, allowed us to achieve a significant reduction in radiation dose compared to standard CT protocols [2]. On average, the effective dose was about 1.5 mSv, which is considered acceptable in view of clinical indications and does not exceed the recommended guidelines. When magnetic resonance imaging data were used, there was no radiation exposure to the patient at all, but MRI protocols require a much longer examination time, which is not always available in the unstable condition of the newborn [5].

Comparison of the results of the present study with the data of the literature indicates a growing interest in the use of 3D technologies in paediatric surgery and neonatology. Many foreign and domestic authors have noted that 3D visualization helps in selecting the least traumatic methods of intervention, allows planning in advance the volume of proposed resections and predicting possible difficulties during surgery. In the future, 3D printing of anatomical models may be more widely implemented, especially in cases of extremely complex heart and large vessel malformations, so that surgeons can tactilely feel the features of the pathology before the intervention.

4. CONCLUSIONS

The study demonstrated that the use of preoperative 3D reconstruction in neonates with congenital malformations significantly improves the quality of planning complex surgical interventions and positively affects the outcome of treatment.

A statistically significant reduction in the duration of surgery and intraoperative blood loss, as well as a lower incidence of complications was observed compared to patients who did not use 3D modeling.

The use of low-dose computed tomography and technologically advanced reconstruction algorithms makes it possible to perform studies with minimal radiation exposure of the child, which is especially important for neonatal practice. High accuracy and visualization of three-dimensional models contributes to a more detailed assessment of the anatomical situation and allows optimal choice of surgical intervention technique. The prospects for further research lie in the integration of 3D printing, virtual reality and augmented navigation, which could bring the quality and safety of surgical procedures to a new level.

The number of collected clinical cases and the variety of congenital pathologies confirm the universality of the proposed approach, and the results obtained are convincing arguments in favour of the routine use of 3D reconstruction in planning operations in newborns.

However, further multidisciplinary studies are needed to include even more data, to assess the long-term results of treatment, and to compare the effectiveness of different 3D modeling algorithms.

Despite some organizational and technical difficulties, the advantages of using 3D reconstruction to plan complex surgical interventions in newborns are obvious and are already influencing the formation of modern neonatal surgery.

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