The role of MRI in diagnostic algorithm of cervicofacial vascular anomalies in children

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Summary

Background: Vascular anomalies are usually diagnosed through their clinical picture and history. The purpose of this study was to assess the role of MR imaging in initial assessment of cervicofacial vascular anomalies in children.

Material/Methods: Twenty pediatric patients with vascular anomalies located in the cervicofacial region underwent MRI examination in our department. Images were evaluated for lesion detectability and its signal characteristics (on T1w, T2w images with fat suppression and contrast enhanced T1w sequences); the extent of the lesions and surrounding tissue involvement were also assessed.

Results: In the studied group MR images revealed all anomalies and provided information of their anatomic extent and invasion of surrounding anatomic structures. Nine hemangiomas and six venous malformations were found among studied patients. Two children had multiloculated lesions corresponding to lymphatic malformations. One examination visualized a lesion consisting mainly of dilated vascular channels with an apparent feeding artery, which was consistent with arteriovenous malformation. Two remaining lesions were mixed malformations. Nine patients had lesions limited to subcutaneous tissue. Two masses infiltrated bone structures. There was muscle involvement found in nine cases.

Conclusions: MR imaging is a well-established method for detection and monitoring of vascular anomalies in children. With ultrasound used mostly for initial diagnosis and additional flow assessment, angiography viewed as an invasive therapeutic method and computed tomography used only in specific situations due to its high irradiation dose, magnetic resonance is the best imaging method used in differential diagnosis and topographical characterization of vascular malformations and tumors of cervicofacial area in pediatric patients. Noninvasively and without irradiation, it enables evaluation of the extent and characteristics of lesions and planning proper therapeutic strategy.

Key words: MRI • hemangioma • vascular malformations • pediatrics

Background

Vascular anomalies comprise a broad group of lesions diagnosed mainly in a pediatric population and constitute an important clinical problem. They may occur in any location, but are most often present within structures of head and neck [1]. According to Mulliken’s and Glowacki’s classification [2] based on cytological and clinical picture adopted by the International Society for the Study of Vascular Anomalies (ISSVA), vascular anomalies are divided into vascular tumors and vascular malformations [3], as shown in Table 1.

Hemangiomas are benign vascular tumors that present at childhood, with increased cellular proliferation and hyperplasia, characterized by slow involution. On the other hand, vascular malformations are congenital lesions formed out of dysplastic vascular canals that do not vanish at later age. Depending on the type of flow, we distinguish slow flow...
malformations, i.e. capillary, venous, lymphatic, mixed, or high flow malformations and arteriovenous fistulas [4].

Commencing treatment with laser therapy, sclerotherapy, embolization or surgical excision as well as prognosis depend on the type of anomaly [3,5]. Due to characteristic appearance of lesions and their temporal evolution, diagnosis is based mainly on clinical features and medical history data [3]. Diagnostic imaging studies are necessary for thorough differential and topographic assessment of lesions, and thus making a decision to commence appropriate treatment [6]. The goal of this work is to determine the role of magnetic resonance imaging (MRI) in the diagnosis of vascular anomalies in children.

Material and Methods

Material

Study group consisted of 20 patients aged 2 months to 10 years with clinically diagnosed vascular anomaly referred to MRI examination at the Department of Radiology of the University Clinical Hospital No 1 in Lodz. Data on patient age, sex, anatomical location of the lesion, performed imaging studies and treatment methods are gathered in Tables 2 and 3.

Methods

MRI examinations were performed with a 1.5T Avanto Siemens scanner (Erlangen, Germany) using a cranio-cervical coil. Study protocol consisted of the following sequences: T1-weighted (TR 409-765, TE 7.8-11 ms) before and after administration of contrast medium with fat saturation and T2-weighted (TR 4440-6340, TE 96-100 ms) with fat saturation performed in three basic planes. Beside two cases (difficulties with establishing i.v. access) patients received intravenous contrast medium (Magnevist in neonates and children up to 7 years old at a dose of 0.2 ml/kg and Gadovist in children older than 7 years at a dose of 0.1 ml/kg). FOV was determined at 23×23 cm, voxel size from 0.5×0.5×3.0 mm to 0.8×0.8×4.0 mm, flip angle between 90 and 150 degrees.

The following criteria were taken into consideration during evaluation of each study: possible assessment of lesion as positive or negative, demarcation of a lesion – good or poor, signal type – hypo, iso- or hyperintense, signal homogeneity, internal structure, degree and homogeneity of contrast enhancement, extent of lesions and degree of displacement and/or infiltration of neighboring structures.

Results

Table 4 presents characteristics of vascular lesions in MRI. In the analyzed group we found 9 hemangiomas, 6 venous malformations, 2 lymphatic malformations, 1 arteriovenous malformation and 2 mixed type malformations. MRI technique enables detecting all anomalies, evaluating their anatomical extent and degree of infiltration of neighboring structures. These lesions were hypo- or isointense in T1-weighted images and hyperintense in T2-weighted images. Following application of contrast medium we acquired strong contrast enhancement in all cases. Nine of 20 lesions were contained within subcutaneous tissue. Significant displacement of surrounding organs was visible in six cases. Involvement of neighboring structures was visualized in 9 patients, including involvement of masseter muscle in five cases and of other facial muscles in four subjects. However, bone infiltration was observed in two cases and encompassed temporal bone and mandible respectively.

Discussion

Clinical assessment of vascular cranio-cervical anomalies in children remains crucial for the diagnostic process.

Table 1. Classification of vascular anomalies according to ISSVA.

| Vascular anomalies | Vascular malformations |
|-------------------|-----------------------|
| Vascular tumors   | Slow-flow             |
| · Hemangiomas (neonatal age, congenital- NICH I RICH) | Capillary |
| · Hemangioendotheliomas | Lymphatic |
| · Dermatological acquired vascular tumors (i.a. pyogenic granuloma) | Venous |
| High-flow         | Arterial malformations |
| · Arteriovenous malformations | Arteriovenous fistulas |

Table 2. Patients’ characteristics.

| No.  | Age     | Sex | Location                        |
|------|---------|-----|---------------------------------|
| 1.   | 7 years | M   | Neck                            |
| 2.   | 5 years 7 m | M | Face-cheek                      |
| 3.   | 5 m     | F   | Face-cheek, canthus             |
| 4.   | 1 year 5 m | F | Face-preauricular area, cheek   |
| 5.   | 11 m    | F   | Neck                            |
| 6.   | 2 m     | F   | Neck                            |
| 7.   | 11 m    | F   | Face-upper lip                  |
| 8.   | 2 years | F   | Face-cheek, oral cavity antrum  |
| 9.   | 4 years 8 m | M | Neck, preauricular area         |
| 10.  | 6 m     | M   | Neck                            |
| 11.  | 1 year 2 m | F | Face-cheek                      |
| 12.  | 6 m     | M   | Face-cheek                      |
| 13.  | 7 years 9 m | F | Face-mandibular area           |
| 14.  | 11 m    | F   | Face-cheek                      |
| 15.  | 4 years 4 m | M | Face-cheek                      |
| 16.  | 11 years 2 m | F | Face-cheek, preauricular area   |
| 17.  | 2 years 7 m | F | Face-cheek, lower lip          |
| 18.  | 10 years | F   | Neck                            |
| 19.  | 8 years 8 m | F | Neck                            |
| 20.  | 4 years 6 m | M | Face-cheek                      |
However, proper radiological assessment in diagnostic imaging studies is necessary to confirm the diagnosis and precisely determine structure of lesions, their size and topographic relationships before planning most effective treatment [3]. Beside MRI technique ultrasonography – including Doppler technique, conventional angiography and computed tomography are also used in the assessment of vascular anomalies [7].

Ultrasound allows for initial assessment of size of lesions, their morphology and, importantly, evaluation of vascular flow [8,9]. It is particularly useful for evaluation of small, superficial lesions [10]. Widespread access, low invasiveness, chance to assess flow and low cost of this study make it the most frequently used diagnostic imaging method in patients with craniocervical vascular anomalies [11]. Being a dynamic study, giving a possibility to apply pressure, it allows for differentiation of hemangiomas, venous and lymphatic malformations and arteriovenous fistulas [8,12]. Ultrasoundography is also used as a good tool for follow-up in order to assess their evolution and for initial assessment of possible complications. Limitations of this method are associated with relatively small tissue range related to the depth of penetration by ultrasounds, minor ability to differentiate and dependence on diagnostician’s experience [13]. In the analyzed group, 11 of 20 patients were referred for ultrasound examination at the first stage of diagnostic process, although due to the need for further evaluation, diagnostics were broadened to include MRI.

Although another diagnostic method – conventional angiography – cannot assess the full extent of pathology, it enables detection of afferent and efferent vessels [14]. It is currently used in case of arteriovenous malformations, mainly as an effective therapeutic modality, for embolization of high flow vascular lesions [9,15,16]. Among the examined patients, embolization of arteriovenous malformation was performed at three stages in one subject, leading to clinically and radiologically apparent improvement.

In case of computed tomography, angiography option can visualize vascular lesions and foci of abnormal vessels together with their supplying vessels [17,18]. CT is excellent at visualizing phlebolites within lesions [19]. However, it is not always possible to clearly differentiate between neighboring tissues and examined lesion [20]. Although in a comparison study Kakimoto et al. did not observe a significant differences in detection of vascular anomalies with CT and MRI [19], the role of CT in a pediatric population remains limited to bone lesions due to the use of ionizing radiation. In such cases, CT facilitates precise determination of degree of bone infiltration [3,17] and enables planning and conducting multidisciplinary treatment involving a pediatrician, vascular surgeon, orthopedic surgeon and a

Table 3. Other diagnostic methods and treatment.

| No. | Diagnosis          | Other examinations        | Treatment                                      |
|-----|--------------------|--------------------------|------------------------------------------------|
| 1.  | Hemangioma         | US                       | Surgical removal and bleomycin injection (several) |
| 2.  | Lymphatic malformation | US                  | Propranolol; laser therapy                        |
| 3.  | Congenital hemangioma | Blood cell scintigraphy |                                                |
| 4.  | Mixed malformation | -                        |                                                |
| 5.  | Hemangioma         | -                        |                                                |
| 6.  | Lymphatic malformation | US                  | Antibiotics, referral to surgery                |
| 7.  | Hemangioma         | -                        | Surgical removal                                |
| 8.  | Venous malformation | US                       | Sclerotherapy (three times)                      |
| 9.  | Venous malformation | US                       | Surgical removal, sclerotherapy (several times), laser therapy |
| 10. | Hemangioma         | US                       | No treatment                                    |
| 11. | Hemangioma         | -                        | Steroid injections (Polcortolon 40, Dexaven)    |
| 12. | Hemangioma         | US                       | No treatment                                    |
| 13. | Arteriovenous malformation | US, angiography    | Embolization with ONYX                           |
| 14. | Hemangioma         | US                       | No treatment                                    |
| 15. | Venous malformation | -                        | Surgical removal, sclerotherapy                 |
| 16. | Venous malformation | Phlebography             | Sclerotherapy                                   |
| 17. | Venous malformation | -                        | Sclerotherapy and surgical removal              |
| 18. | Mixed malformation | -                        |                                                |
| 19. | Venous malformation | US                       | Sclerotherapy (two times) and surgical removal  |
| 20. | Hemangioma         | US                       | Surgical removal                                |
Table 4. MRI characteristics of vascular anomalies in the studied group.

| No. | Diagnosis                  | Demarcation      | Character of signal in MRI sequences | Signal homogeneity | Signal loss within a lesion | Internal structure of a lesion | Contrast enhancement | Homogeneity of contrast enhancement | Lesion extent (skin, subcutaneous tissue, infiltration of muscles and bone structures) | Afferent and efferent lesions | Degree of displacement of neighboring tissues |
|-----|----------------------------|------------------|--------------------------------------|-------------------|-----------------------------|-------------------------------|---------------------|-------------------------------------|----------------------------------------------------------------------------|-----------------------------|---------------------------------------------|
| 1.  | Hemangioma                 | Well demarcated  | Iso                                  | Hyper             | Quite homogeneous           | –                             | ++                  | Quite homogeneous                | Subcutaneous tissue suprascapular                                                      | Numerous vessels involved in venous drainage | ++                                         |
| 2.  | Lymphatic malformation     | Weakly demarcated| Iso                                  | Hyper             | Heterogeneous              | –                             | Multicystic         | ++                                  | Quite homogeneous                        | Subcutaneous tissue half of the face           | –                                         |
| 3.  | Hemangioma                 | Well demarcated  | Iso                                  | Hyper             | Quite homogeneous           | –                             | ++                  | Quite homogeneous                | Subcutaneous tissue of upper palpebra, angle of the eye, infiltrating the orbit | –                                         |
| 4.  | Mixed malformation         | Weakly demarcated| Iso                                  | Hyper             | Quite homogeneous           | –                             | Foci of tortuous and dilated vessels within a tumor | ++                                  | Quite homogeneous                        | Skin, subcutaneous tissue of half of the face and neck, masseter muscle | –                                         |
| 5.  | Hemangioma                 | Well demarcated  | Iso                                  | Hyper             | Quite homogeneous           | –                             | ++                  | Homogeneous                      | Subcutaneous tissue                                      | Supplied by right thyrocervical trunk, drainage through occipital vein | –                                         |
| 6.  | Lymphatic malformation     | Well demarcated  | Iso/hypo                            | Hyper             | Heterogeneous              | –                             | Multicystic + (wall) | Homogeneous within walls          | Subcutaneous tissue                                      | –                                         |
| 7.  | Hemangioma                 | Well demarcated  | Iso                                  | Hyper             | Homogeneous                | –                             | ++                  | Homogeneous                      | Entire thickness of upper lip, muscles of the upper lip | –                                         |
| 8.  | Venous malformation        | Weakly demarcated| Iso                                  | Hyper             | Heterogeneous              | –                             | Numerous bands of fluid       | ++                                  | Heterogeneous                           | Masseter muscle, pterygoid muscle, parotid gland, sublingual salivary gland and base of the tongue | –                                         |
| 9.  | Venous malformation        | Quite well demarcated| Iso                                  | Hyper             | Heterogeneous              | –                             | Microlobular                   | +                                   | Heterogeneous                           | Parotid gland, subcutaneous tissue, masseter muscle | –                                         |
| 10. | Hemangioma                 | Quite well demarcated| Hypo                                 | Hyper             | Heterogeneous              | +                             | Numerous vessels              | ++                                  | Quite homogeneous                 | Subcutaneous muscle               | –                                         |

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Table 4 continued. MRI characteristics of vascular anomalies in the studied group.

| No. | Diagnosis                  | Demarcation (well demarcated/ weakly demarcated) | Character of signal in MRI sequences | Internal structure of a lesion | Homogeneity of contrast enhancement | Lesion extent (skin, subcutaneous tissue, infiltration of muscles and bone structures) | Afferent and efferent lesions | Degree of displacement of neighboring tissues |
|-----|----------------------------|--------------------------------------------------|-------------------------------------|--------------------------------|-----------------------------------|--------------------------------------------------------------------------------|-----------------------------|---------------------------------------------|
| 11  | Hemangioma                 | Quite well demarcated                            | Hypo Hyper Homogeneous +            | Numerous tortuous and dilated vessels within a lesion; | ++                      | Quite homogeneous Skin, subcutaneous tissue, platysma, muscles of facial expression, cartilaginous part of nares | Drainage through facial vein | +                                          |
| 12  | Hemangioma                 | Weakly demarcated                                | Iso Hyper Homogeneous +            | Microlobular, numerous vessels within a lesion       | + +                     | Homogeneous Subcutaneous tissue                                                | –                           | +                                          |
| 13  | Arteriovenous malformation | Quite well demarcated                            | Iso/Hypo Hyper Heterogeneous +     | Numerous vessels                                        | –                       | Heterogeneous Mandibular body                                                   | +                           | ++                                         |
| 14  | Hemangioma                 | Quite well demarcated                            | Iso Hyper Homogeneous +            | –                                                        | +                       | Homogeneous Subcutaneous tissue, masseter muscle, parotid gland                | +                           | +                                          |
| 15  | Venous malformation        | Well demarcated                                  | Iso Hyper Heterogeneous +          | Heterogeneous, spongyanous                          | Na                     | Na Subcutaneous tissue                                                          | –                           | +                                          |
| 16  | Venous malformation        | Weakly demarcated                                | Iso Hyper Homogeneous –            | –                                                        | ++                     | Heterogeneous Subcutaneous tissue, muscles (masseter, pterygoids), alveolar processes | –                           | +                                          |
| 17  | Venous malformation        | Weakly demarcated                                | Iso Hyper Heterogeneous –          | –                                                        | +                     | Heterogeneous Entire thickness of lower and upper lip up to the mucosa          | –                           | +                                          |
| 18  | Mixed malformation         | Weakly demarcated                                | Iso Hyper Heterogeneous –          | Fluid-filled and solid spaces                        | + +                     | Heterogeneous Subcutaneous tissue, pyramid of temporal bone, tongue, mandibular angle | –                           | ++                                         |
| 19  | Venous malformation        | Weakly demarcated                                | Iso Hyper Heterogeneous –          | –                                                        | +                     | Heterogeneous Subcutaneous tissue of lateral part of neck                      | –                           | +                                          |
| 20  | Hemangioma                 | Well demarcated                                  | Iso Hyper Homogeneous –            | –                                                        | na na                  | Subcutaneous tissue                                                            | –                           | +                                          |

radiologist. None of the patients from our group had computed tomography performed. Due to good tissue contrasting, multilevel imaging and absence of ionizing radiation MRI is an excellent method for the diagnosis of vascular anomalies in children. It can
Spin-echo, fat saturation sequences: T2-weighted and T1-weighted with contrast, are of the greatest value in the diagnostics of vascular malformations [19]. T2-weighted sequences with fat saturation can precisely evaluate of lesions located superficially and differentiation from subcutaneous fat tissue [28] and T1-weighted sequences after contrast administration enable determining their full extent due to characteristic enhancement. Gradient T2-weighted sequences that enable hemosiderin detection and assessment of rapid vascular flow are also useful [22].

Specific types of vascular anomalies present with characteristic picture in MRI examination and thus it is possible to differentiate them using this technique [7,29].

In the analyzed group lesions were of hypo- or isointense character in T1-weighted images and hyperintense in T2-weighted images, which is in accordance with literature data [19,30].

Hemangiomas are usually well-demarcated tumors, not infiltrating, hypo- or isointense compared to muscles in T1-weighted images [3,31]. They are hyperintense, often heterogeneous in T2-weighted images and exhibit strong contrast enhancement. Loss of signal in spin-echo sequences corresponds to rapid-flow vessels, often visible in the central part and on the peripheries of lesions [21]. In the examined group we found 9 hemangiomas (Figure 1) visualized as solid lesions, rather well-demarcated from the surroundings – 8/9 lesions, isointense in T1-weighted images – 7/9, hyperintense in T2-weighted images – 9/9, with homogeneous signal – 8/9 and strong contrast enhancement 7/9. Similar results were acquired in other studies – five cases of hemangiomas in a group of 23 vascular anomalies in a study by Meyer et al. are solid lesions of medium signal in T1-weighted images, high signal in T2-weighted images, enhanced following administration of contrast medium, with signs of rapid flow [29].

Lymphatic malformations often appear as heterogeneous, cystic structures of low or medium signal in T1-weighted and high in T2-weighted images and exhibit contrast enhancement within walls and septa [22]. Fluid levels are seen in case of large multicystic lesions [3,22]. Among studied patients there were two lymphatic malformations presenting with characteristic, multicystic image in MRI examination with enhancement of cystic walls (Figure 2). Similar results were described in the literature [32,33].

In MRI examination venous malformations are visible as lobulated, serpentine, poorly demarcated lesion with septa, hypo- or isointense in T1-weighted images. Due to the presence of venous sinuses they are hyperintense in T2-weighted images and do not exhibit signs of flow [1,3]. Rarely occurring but characteristic loss of signal on T2-weighted images or phlebolites, be caused by the presence of clots in veins (Figure 3A) [3,9,22,23].

Figure 1. 11-month-old girl with a hemangioma of the right cervical region. (A) T2-weighted image with fat suppression, transverse plane. (B) T1-weighted image with fat suppression after contrast administration, transverse plane.

Figure 2. 2-month-old girl with a lymphatic malformation of the left parapharyngeal space. (A) T2-weighted image with fat suppression, transverse plane. (B) T1-weighted image with fat suppression after contrast administration, transverse plane.
Diffuse contrast enhancement of the entire lesion, delayed in a dynamic study, is seen in venous malformations (Figure 3B). In the studied group venous malformations were usually poorly demarcated lesions (4 of 6 lesions). They were all characterized by medium signal in T1-weighted and high signal in T2-weighted images, usually involving neighboring muscles aside from subcutaneous tissue (4 of 6 lesions). All six patients underwent sclerotherapy, some of them several times, according to the methods used by other authors at other facilities [34].

In case of arteriovenous malformations MRI examination visualizes a lesion containing small component of tissue, consisting of dilated afferent and efferent vessels and numerous connecting vascular canals with visible loss of signal in spin-echo sequences, indicating high flow within them [23,35]. Early venous filling is visible following administration of contrast medium and magnetic resonance dynamic angiography with administration of contrast enables assessment of flow dynamics [36]. Differentiation from other high-flow malformations is possible due to characteristic serpentine loss of signal, lack of dominating tissue mass and frequent involvement of bone structures with attenuation of signal in T1-weighted sequences [4,23,29,36]. One arteriovenous malformation and its feeding vessel consisting of numerous vascular structures located within mandibular corpus was visualized in our study (Figure 4).

Capillary malformations usually do not require imaging except for cases of coexisting developmental abnormalities [3]. MRI examination may show nonspecific thickening of skin and subcutaneous tissue [37].

Specific types of malformations may occur within one vascular lesion as mixed malformations. Administration of contrast medium enables differentiation between solid and cystic parts of pathologic mass, which is in accordance with our observations. Assessment of the venous and lymphatic component in slow-flow malformations consists of various patterns of contrast enhancement. On the other hand, in case of lymphatic malformations only cystic septa and walls undergo enhancement [38]. There were two mixed malformations with a venous and lymphatic component diagnosed in our study group.

Magnetic resonance technique is also appropriate for monitoring of treatment response and follow-up of possible recurrences [7,22].

Conclusions

Magnetic resonance examination preceded by a careful clinical examination is an effective and safe imaging modality. It aids in characterizing vascular anomalies in children. It enables thorough assessment of lesions and thus, proper planning of treatment. It may be useful in monitoring of therapeutic progress. MRI is advantageous compared to ultrasound in the evaluation of the extent of lesions and their topographic relationships.
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