Diploma thesis

TREATMENT OF VASCULAR MALFORMATIONS IN CHILDHOOD AND ADOLESCENCE

Submitted by

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Graz, 17. April 2014 *Diellor Rizaj*

Affidavit

I, hereby, declare that the following diploma thesis has been written only by the undersigned and without any assistance from third parties. Furthermore, I confirm that no sources have been used in the preparation of this thesis other than those indicated in the thesis itself.

Graz,am 17. April 2014 *Diellor Rizaj*

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I owe my deepest gratitude to my parents, who were always supporting me during my studies.

Zusammenfassung

Hintergrund: Vaskuläre Fehlbildungen sind angeborene Defekte im Rahmen von Vaskulogenese, Angiogenese und Lymphangiogenese. Sie sind bei der Geburt vorhanden, wachsen proportional mit dem Kind mit und bilden sich nie zurück. Die angeborenen vaskulären Fehlbildungen können lokalisiert oder infiltrierend sein. Sie können überall im Körper auftreten, vor allem im Kopf-Hals-Bereich, an den Extremitäten und am Rumpf.

Material und Methoden: Im Rahmen einer retrospektiven Studie wurden alle Patienten analysiert, welche aufgrund von vaskulären Fehlbildungen an der Grazer Kinder- und Jugendchirurgie operiert oder konservativ behandelt wurden. Bei der Erfassung der Daten aus dem Zeitraum 01.01.1991 - 31.12.2010 wurden die Entlassungsdiagnosen, die klinische Symptomatik, die Ergebnisse der durchgeführten Bildgebungen, die histologischen Befunde, sowie die Art der operativen und/oder konservativen Therapie während des Krankheitsverlaufes ausgewertet. Es folgen eine Darstellung der Ergebnisse mittels deskriptiver Statistik sowie ein Vergleich der Ergebnisse mit der geläufigen Literatur.

Ergebnisse: Im genannten Zeitraum wurden 97 Patienten behandelt. Die Geschlechtsverteilung von weiblich zu männlich war 1.1: 1. Die Verteilung der vaskulären Malformationen zeigte sich wie folgt: lymphatische Malformationen (LM) in 38.1%, venöse Malformationen (VM) in 25.7%, arteriovenöse Malformationen (AVM) in 17.5%, kapilläre Malformationen (CM) in 5.1% und gemischte vaskuläre Malformationen in 13.4% der Fälle. Anatomische Verteilung dieser Läsionen war wie folgt: in 22% im Kopf-Halsbereich, in 31% am Rumpf und in 45% zusammen an der oberen und unteren Extremitäten. Als radiologische Diagnostik kamen folgende Verfahren zur Anwendung: Magnetresonanztomographie - Angiographie (MRT-MRA) in 53% und Sonographie (US) in 38%. Ebenfalls hilfreich waren auch Röntgen in 5% und CT in 4% der Fälle. Die bevorzugte Behandlungsmethode war die komplette chirurgische Resektion in 66%, gefolgt von chirurgischer Teilresektion in 9%, der Lasertherapie allein oder in Kombination mit anderen Modalitäten in 7%, der Sklerotherapie in 3%, der Embolisation in 2% und der konservativen Therapie in 13% der Fälle.

Schlussfolgerung: Für die erfolgreiche Behandlung von Patienten mit vaskulären Malformationen ist es besonders notwendig alle therapeutische Modalitäten zu kennen und bei Bedarf alleine oder in Kombination einsetzen zu können, mit einem Hauptziel die Patienten zu heilen und die Wiederkehr dieser Läsionen zu verhindern.

Abstract

Background: Vascular malformations are congenital developmental defects of vasculogenesis, angiogenesis and lymphangiogenesis. They are present at birth, grow in proportion with the child and never regress. The congenital vascular malformations may be localized or infiltrative. They may occur anywhere in the body, especially in the head and neck region, extremities and the trunk.

Materials and Methods: A retrospective study of patients treated during the period of 01.01.1991 – 31.12.2010 was performed. All children with vascular malformations, who have been treated at the Department of Pediatric and Adolescent surgery of the Medical University Graz were included into this study.
During the acquisition of the data these parameters were analyzed: the discharge diagnosis, the clinical presentation, the results of conducted imaging, the histological findings, as well as the outcome after operative or non-operative therapy. The data have been analyzed by descriptive statistics and compared with the current literature.

Results: During the study period 97 patients were treated. The gender distribution of females to males was 1.1:1. The types of vascular malformations were as follows: lymphatic malformations (LM) in 38.1%, venous malformations (VM) in 25.7%, arteriovenous malformations (AVM) in 17.5%, capillary malformations (CM) in 5.1% and combined vascular malformations in 13.4% of patients. Anatomic distributions of these lesions were as follows: in 22% in the head and neck region, in trunk in 31% and all together in the upper and lower extremities in 45% of the patients.
The following radiological diagnostic procedures were used: magnetic resonance imaging - angiography (MRI -MRA) in 53% and ultrasonography (US) in 38%. Also helpful were X-rays in 5% and CT in 4% of patients. The preferred treatment modality was complete surgical resection in 66% of patients, followed by partial resection in 9%, lasertherapy alone or in combination with other modalities in 7%, sclerotherapy in 3%, embolization in 2% and non-operative therapy in 13% of patients.

Conclusion: For successful treatment of patients with vascular malformations it is crucially important to be able to use all different treatment modalities alone or in combination, with a main goal to completely cure the patients and avoid the recurrence of these lesions.

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Abbreviations

ISSVA	International Society for the Study of Vascular Anomalies
LM	Lymphatic Malformation
VM	Venous Malformation
CM	Capillary Malformation
AVM	Arteriovenous Malformation
AVF	Arteriovenous Fistula
AM	Arterial Malformation
CLM	Capillary-Lymphatic Malformation
CLVM	Capillary-Lymphatic-Venous Malformations
CVM	Capillary-Venous Malformation
LVM	Lymphatic-Venous Malformation
PWS	Port-Wine-Stain
BRBN	Blue-Rubber-Bleb-Naevus-Syndrom
KTS	Klippel-Trenaunay-Syndrom
SWS	Sturge-Weber-Syndrom
KMS	Kasabach-Merrit-Syndrom
VEGF	Vascular Endothelial Growth Factor
Et al.	And others
MRT (I)	Magnetic resonance tomography (imaging)
MRA	Magnetic resonance angiography
X-ray	Roentgen, Radiography
US	Ultrasonography, Ultrasound
CT	Computed tomography
RICH	Rapidly Involuting Congenital Hemangioma
NICH	Non-Involuting Congenital Hemangioma

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1. INTRODUCTION

1.1. Review of the literature

1.1.1. Classification

Vascular anomalies are developmental malformations or types of neoplasia, Dupuytren called them “erectile tumors”. Other nineteenth century words used for vascular anomalies were "neavus Maternus" or ‘’stigma metrocelis’’, as a Latin medical term. People believed that a mother can, during pregnancy, be the cause of a so-called birthmark, strawberries, grapes, etc. due to longing for something or her aversion to them and from negative emotions [2,3,6].

In the past the classification of vascular birthmarks was unclear and confusing [1]. Rudolf Virchow was the first to try to classify them histopathologically defining them as an angioma simplex, angioma cavernosum and angioma racemosum [4].

Wegener, a student of Virchow, later on proposed suchlike classification of lymphatic lesions: lymphangioma simplex, cavernosum and cystic. He supposed that these lesions may be due to lymphatic inflammation, developmental malformation or endothelial proliferation [13].

In 1982, Mulliken and Glowacki introduced the biological classification of vascular anomalies. They divided all vascular lesions into vascular tumors and vascular malformations [6,13].

Hemangiomas	Vascular malformations
Clinical	
Usually not seen at birth 30% present as red macule	All present at birth - may not be evident
Rapid postnatal proliferation and slow involution	Commensurate growth may expand as a result of trauma, sepsis or hormonal modulation
Sex ratio F:M - 3:1	F:M – 1:1
Cellular	
Plump endothelium with increased turnover	Flat endothelium, slow turnover
Increased mast cells	Normal mast cell count
Multilaminated basement membrane	Normal thin basement membrane
Capillary tubule formation	Poor endothelial growth in vitro
Hematological	
Thrombocytopenia (Kasabach-Merrit-Syndrom)	Primary stasis (Venous), localized consumptive coagulopathy

Table 1 [73] shows the differentiation of hemangiomas from vascular malformations, based on their clinical, histological and hematological characteristics (modified from Mulliken and Glowacky 1982).

In 1996 at the International Society for the Study of Vascular Anomalies (ISSVA) meeting in Rome, the first classification of vascular malformations was proposed, as single vessel type and combined forms [13]. The nomenclature has always been presented as a major problem. A universal classification is of great importance, because the distinct vascular tumors and vascular malformations may require different therapeutic techniques.

Single vessel type

– capillary

– venous

– lymphatic

– arterials

Combined malformations

– arteriovenous

– lymphaticovenous

– capillary-venous

– capillary-lymphaticovenous

Table 1.1 Vascular anomaly classification (ISSVA) in 1996 [13].

ISSVA made a uniform nomenclature based on the findings of Mulliken and Glowacki, taking into consideration their hemodynamic characteristics, dividing vascular malformations into low-flow and high-flow and adding a complex combined syndromes with their varieties [13,23,71].

Slow flow

– Capillary (CM)

– Lymphatic (LM)

– Venous (VM)

Fast flow

– Arterial (AM): aneurysm, coartaction, ectasia

– Arteriovenous fistulas (AVF)

– Arteriovenous (AVM)

Complex combined (often with associated skeletal overgrowth) – Regional syndromes

Sturge Weber: facial CM, intracranial CM, VM, AVM

Klippel-Trenaunay: limb-truncal capillary lymphaticovenous (CLVM)

Parkes-Weber: limb CLVM with AVF

– Diffuse syndromes

Maffucci: LVM, enchondromas

Solomon: CM, VM, intracranial AVM, epidermal nevi, etc.

Proteus: CM, VM, macrodactyly, hemihypertrophy, lipomas, pigmented nevi, scoliosis

Table 2. Classification of vascular malformations according to Mulliken and Glowacky [13].

This classification system of ISSVA is still the most accepted, with great advances in understanding of the pathophysiology, morphology, classification, nomenclature and treatment.

Belov, Malan and Degni at the seventh meeting of the ISSVA in Hamburg in 1988 formed the Hamburg Classification of congenital vascular defects. The Hamburg Classification is based on embryological development [13]. Belov et al. [42] introduced an etiologic and pathophysiologic classification system focused on the embryologic site of origin of the defect that led to the development of each particular malformation. Depending on vessel defects the Hamburg classification divides vascular anomalies in 5 types and 2 morphologic forms (truncular and extratruncular):

	Forms	
Types	**Truncular**	**Extratruncular**
Predominantly arterial defects	Aplasia or obstruction Dilatation	Infiltrating Limited
Predominantly venous defects	Aplasia or obstruction Dilatation	Infiltrating Limited
Predominantly lymphatic defects	Aplasia or obstruction, Dilatation	Infiltrating Limited
Predominantly AV shunting defects	Deep Superficial	Infiltrating Limited
Combined/mixed defects	Arterial and venous Without shunt Hemolymphatic with or without shunt	Infiltrating hemolymphatic Limited hemolymphatic

Table 3. Anatomophatologic classification of vascular defects (Hamburg classification) [13].

One of the Hamburg disadvantages of the Hamburg Classification is that it does not describe capillary malformations [13].

The Hamburg Classification of vascular anomalies is relatively similar to the ISSVA Classification, it is however strongly based on the defects in the early stage of embryogenesis and therefore may be of an advantage when classifying anomalies such as aplasias, stenosis or aneurysms which are not well classified in the ISSVA nomenclature.

	Vascular Tumor		Vascular Malformation		
	Infantile hemangioma	**Hemangio endothelioma**	**Origin**	**Embryological defect**	**Compartment**
What	Stage I Prodromal II Initial III Proliferation IV Maturation V Regression	Type Rapid involuting (RICH) Non involuting (NICH) “Tufted” angioma Kaposiform	Venous Lymphatic Arterial Arteriovenous Capillary Mixed	Aplasia Hypoplasia Extratruncular Dysplasia Hyperplasia Hamartoma	Truncular
		Organ			
Where	Intra/subcutaneous Intracranial	Intra/submucous Parenchymatous	Intramuscular Intracavitar	Intraosseous/intra-articular Mesenterial	
		Number			
Singular		Multipl e		Disseminated	
		Localiza tion			
	Peri/intra-orbital Perimammary	Peri/intra-auricular Head/neck Peri/enoral Anogenital/intra-anal/ Intestinal	Laryngo-tracheal Trunk (other)	Face (other) Acral/hand/feet	Extremities (other)
How		***Growth***			
	Limited	Moderate infiltrative	High infiltrative		
		Complic ation			
	Exulceration Excess growth	Infection Cardiac failure Vent. Obstruction Feedings problems	Bleeding Intestinal obstruction	Intravasc. Coagulopathy Visual obstruction	Assoc. defects

Table 3.3. Classification of congenital vascular anomalies [13].

For the characteristics of Hamburg Classification is that this classification is answering three major questions ‘’what’’, ‘’where’’ and ‘’how’’ concerning the vessel type affected in malformation, the location of the vascular anomaly and the impact of the vascular anomaly on the organism.

1.2. Vascular tumors

Hemangiomas are benign tumors with a proliferation of vascular endothelium, they occur in the first days and weeks after the birth. Infantile hemangiomas are the most common type of vascular anomalies. They are clinically easy to diagnose and must be differentiated from vascular malformations and combined syndromes [13,23]. After birth hemangiomas proliferate for several months, then a stationary period and the period of involution for some years. Hemangiomas have a female to male ratio up to 5:1. The body distribution of hemangiomas is in 60% in the face and neck region, in 25% in the trunk and in 15% in the extremities [22,48,67].

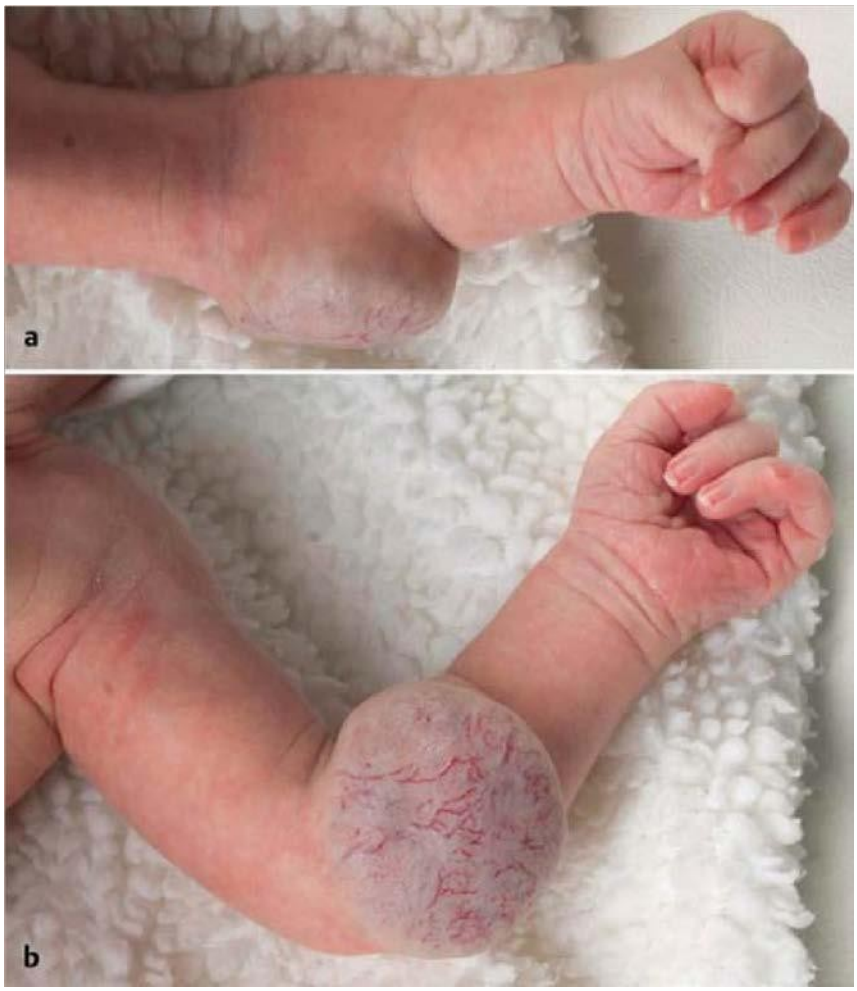

Figure 1 a and b. Newborn child with congenital Hemangioma of the left arm.

1.3. Vascular malformations

Vascular malformations occur due to congenital development defect of vasculogenesis, angiogenesis and lymphangiogenesis. They are always present at birth, even not always visible, grow in proportion with child and never regress. Depending on the vessel type they affect, capillary, venous and lymphatic are "slow-flow" malformations, arterial and arteriovenous are "fast-flow" malformations, adding a syndromes of complex cases with each other [6,7,13].

Tasnadi et al. [13] performed a study on 3753 three-year-old children and found in 43 cases congenital vascular malformations, resulting an incidence of 1.2% in a 3 years old population. Out of these 48,5% were venous malformations, 35.8% arterio-venous shunts defects, 10% were lymphatic malformations and combined forms were found in 5,7% of cases.

1.3.1. Low-flow malformations

1.3.1.2. Capillary malformations

Capillary malformations (CM) also called port-wine stain or nevus flammeus are present at birth as pink or red flat skin lesions and may involve small or large areas. CMs are hemodynamically inactive vascular malformations of slow blood flow velocity, which are related to the capillary network of the skin and mucous membranes. They can occur anywhere on the skin, with head and neck region, especially commonly affected. Furthermore they can appear isolated or in combination with other abnormalities [14,23,48]. CM is

characterized histologically by an increased number of vascular ectactic vessels in the dermis [15]. It has been reported that the vascular endothelial growth factor (VEGF)-A and the receptor VEGF-R2 expression are more increased in capillary malformations skin tissues [16]. Boon et al. [18] have identified mutation of RASA1 on chromosome 5q, that encodes GTPase-activating protein, which regulates the vascular development. That is not limited just to a CM, but occurs also in other combination of vascular malformations [17,19,20].

1.3.1.3. Venous malformations

Venous malformations (VM) are the most common of all vascular malformations and they belong to a group of "slow-flow" malformations. The main locations of VM are head and neck (40%), extremities (40%) and trunk (20%) and with a proportional gender ratio [23]. VM are usually asymptomatic (depend from size and location) as pain, ulceration, cosmetically deforming, bleeding, abnormal bone growth, fractures, etc. They most commonly involve skin, subcutis and mucosa but they may also infiltrate bone, muscle and other organs [13,23,70].

VM has an autosomal dominant gene mutation on a chromosome 9p and it can be passed through family of 1% of vascular malformations cases [10,69].

1.3.1.4. Lymphatic malformations

Lymphatic malformations (LM) are slow-flow lesions that mainly occur during embryonic development, through disruption of lymphatic drainage. They usually present at birth but can be seen at any age. They can be divided in macro cystic, micro cystic and mixed. The macro cystic lymphangiomas are characterized by cysts in diameter >2 cm. Microcystic malformations also called Lymphangioma circumscriptum are most common LM [25,63]. LM can be located include neck and axilla with less common locations in mediastinum, pelvis and retroperitoneum. LM that occur in neck and axilla, are often called cystic hygromas [22]. LM usually involve the subcutaneous tissues, but also may be affected muscle, bone and rarely visceral organs such as gastrointestinal tract or lungs [2].

Both genders are equally affected and 1 out of 1700 newborns is born with LM. It has been found that cell signals over VEGF-C may be involved in the formation of LM, causing lymphatic hyperplasia. It has been suggested that VEGF-C and VEGFR-3 represent peripheral dilatation of lymphatic vessel [27,59].

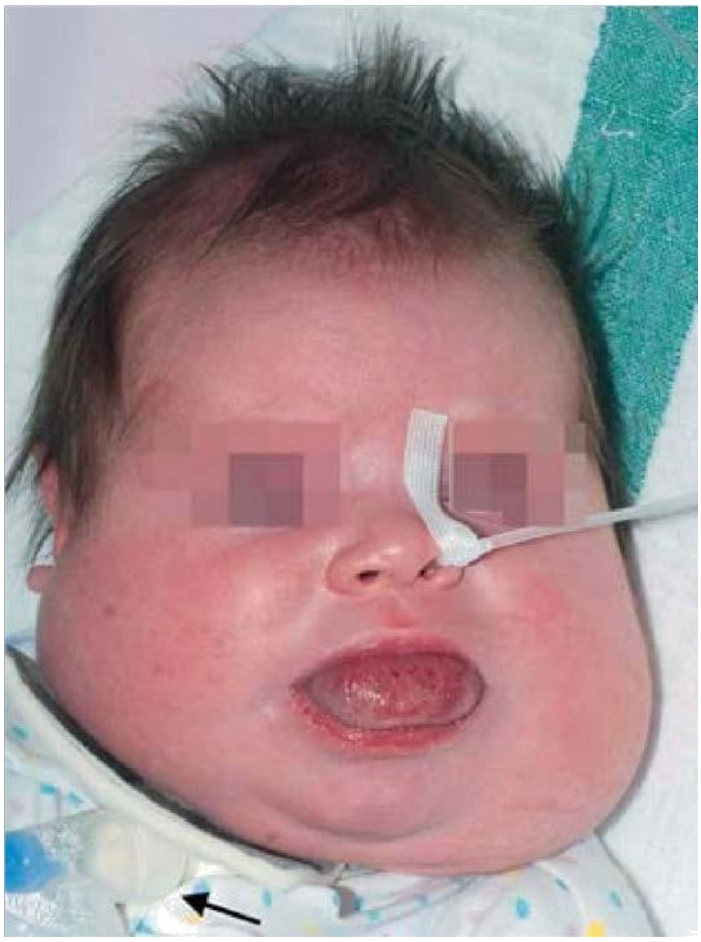

Figure 2. Newborn child with lymphatic malformations in the neck region, with diffuse infiltration of the tongue

1.3.2. Fast - flow malformations

1.3.2.1. Arterial malformations

Arterial malformations (AM) are rarely described or discussed in the literature as compared to other vascular malformations. The clinical status is variable and depends on the location and type of abnormality [49]. The structural changes include congenital hypoplasia, ectasia, stenosis and aneurysms. They are almost always asymptomatic but they may also present with pain, bleeding, heart failure, low perfusion of the lower extremities and headache [49].

1.3.2.2. Arteriovenous malformations

Arteriovenous malformations (AVM) are characterized by abnormal communication between arteries and veins, creating the so-called nidus (shunts). Arterial feeders and enlarged draining veins connect through micro and macro fistulas [22,49]. AVM may occur in any part of the body.

The Schobinger staging system [38] accepted by the International Society for the Study of Vascular Anomalies, describes four stages of AVMs:

Stage I lesions (quiescent phase) are asymptomatic,

Stage II lesions (progressive phase) show increased warmth and murmur on auscultation,

Stage III lesions are characterized by destructive lesions and are associated with pain, bleeding, ulceration and bone erosions,

Stage IV lesions are defined by cardiac decompesation with congestive heart failure.

Gender distribution by AVM is equal, around 40-60% are present at birth, the other 40-60% may be present in the childhood or early adulthood.

1.3.2.3. Arteriovenous fistulas

The congenital AVFs lesions are the result of missed separations of the arteriovenous connection during the embryonic development. Acquired AVFs are usually the result of a trauma, which may lead to one or more connections between arteries and veins.

1.3.3. Various syndromes

Various syndromes can be seen in association with one or more vascular malformations, each of which have been given eponyms. Here only the most important will be discussed. They are capillary, arterial, venous, lymphatic and arteriovenous syndromes.

The main list of the important syndromes follows: table 4 from ISSVA

Regional syndromes
Sturge Weber: facial CM, intracranial CM, VM, AVM
Klippel-Trenaunay: limb-truncal capillary lymphaticovenous (CLVM)
Parkes-Weber: limb CLVM with AVF
Diffuse syndromes
Maffucci: LVM, enchondromas
Solomon: CM, VM, intracranial AVM, epidermal nevi, etc.
Proteus: CM, VM, macrodactyly, hemihypertrophy, lipomas, pigmented nevi, scoliosis

Table 4. Vascular malformations in the frame of various syndromes

Struge Weber Syndrome SWS is characterized by the presence of cutaneous port wine stain in the area of the first trigeminal branch, associated with vascular anomalies of the leptomeninges and ocular anomalies, with symptoms such as seizures, half-side paralysis and mental retardation [13].

Klippel-Trenaunay Syndrome KTS is characterized by the presence of a cutaneous nevus capillary malformation associated with venous malformation and sometimes with lymphatic malformations, this malformation CLVM usually involves one or more extremities (lower limbs) and is associated with prominent soft tissue and bone hypertrophy [13,50].

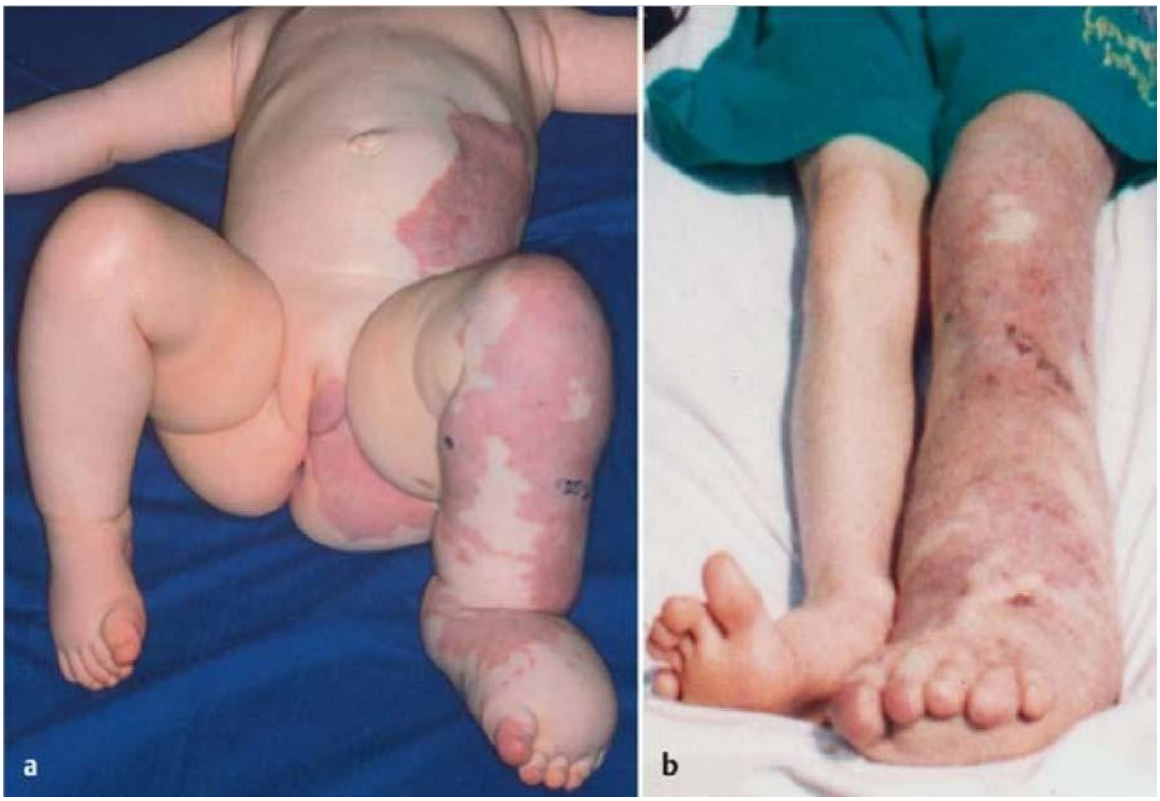

Figure 3 a and b. Klippel-Trenaunay Syndrome the same patient with 7 months (a) and (b) 9 years.

Proteus Syndrome is characterized by overgrowth of bones in the extremities, fingers, toe and it is associated with benign tumors such as fibroma, lipoma and epidermal nevus. This disorder is sporadic and progressive over time. Vascular, skeletal and soft tissue anomalies can be asymmetric and variably expressed [13,50].

Cutis marmorata teleangiectatica congenita is characterized by the presence of teleangiectasia in the limbs presenting purplish reticular network [13].

Rendu Osler disease, which is characterized by skin and mucosal teleangiectasis, and **Ataxia teleangiectasia** which is characterized by ocular and cutaneous teleangiectasia, progressive cerebellar ataxia and immune deficiency [13].

Parkes Weber Syndrome affects limbs, trunk and lower extremities. It is characterized by the presence of skin nevi, bone and muscle hypertrophy, venous dilatation and AV malformation [13,50].

Cobb syndrome caused by the Superficial AVMs in the trunk and Bonnet

Dechaume Blanc syndrome caused by diffuse AV shunts which involve the face, retina and the brain [13].

Gorham Stout syndrome is caused by lymphatic and sometimes venous malformations, with bone invasion and destruction [13].

Maffucci Syndrome is usually not evident at birth, and may present with bone lesions and enchondromas in childhood, and the venous anomalies appear later in age [50].

Bean syndrome or blue rubber bleb nevus syndrome BRBN presents with multiple venous lesions on the skin, hyperkeratotic spots, blebs and dilated veins [13].

1.4. Clinical presentation of vascular malformations

1.4.1. Venous malformations are the most common form of vascular malformation, usually they are blue gray in color and grow slowly over time. They can be small and varicose or large and extensive, involving the extremities, face or trunk, but may also involve visceral organs. Common complication of venous malformations is Phlebothrombosis, causing pain, swelling and stiffness of joints and muscles. The location and size is important for the clinical pathology. Venous malformations in the craniofacial region may cause obstructive ocular and breathing complications such as exophthalmia and apnea. Superficial lesions may be cosmetically deforming. The lesions that involve muscle or bone may lose function and result with pathologic fractures [13,23,48,50].

1.4.2. Capillary malformations known as port-wine stains may occur anywhere on the body. These lesions often manifest as discolorations of the skin, CM on the face may follow a dermatomal distribution. Lesions may involve the mucosal membranes and may cause deformity of the face with bones hypertrophy and gingival hyperplasia [30]. The presence of CM needs careful observation, because of the possibility of anatomically associated defects of central nervous system, such as meninges, AVMs of the spinal cord, lipomeningocele or spinal abnormalities [30,31].

1.4.3. Lymphatic malformations may be present in any part of the body and can be found most commonly in the head and neck region, mediastinum, chest, axilla, peritoneum, retroperitoneum and extremities [34,62]. In case of dermal involvement these malformations cause severe disfigurement with discoloration, with dark red small vesicles. Complication of LMs with a result of intralesional hemorrhage can affect up to 12% of cases [35]. LMs of the cervicofacial region may be associated with ophtalmologic symptoms, dental and airway problems, and may necessitate tracheostomy [36,37].

1.4.4. Arteriovenous malformations may be present at birth, appear as small discolored area on the skin, resulting with erythema and rubor. Local ischemia may manifest with pain, ulceration and bleeding. The presence of large arteriovenous shunts may lead to heart failure. AVMs can occur anywhere on the body, however they occur most commonly intracranially, thereafter in the head, neck, extremities, trunk and visceral organs. These lesions may grow fast during puberty [13, 23, 30, 33].

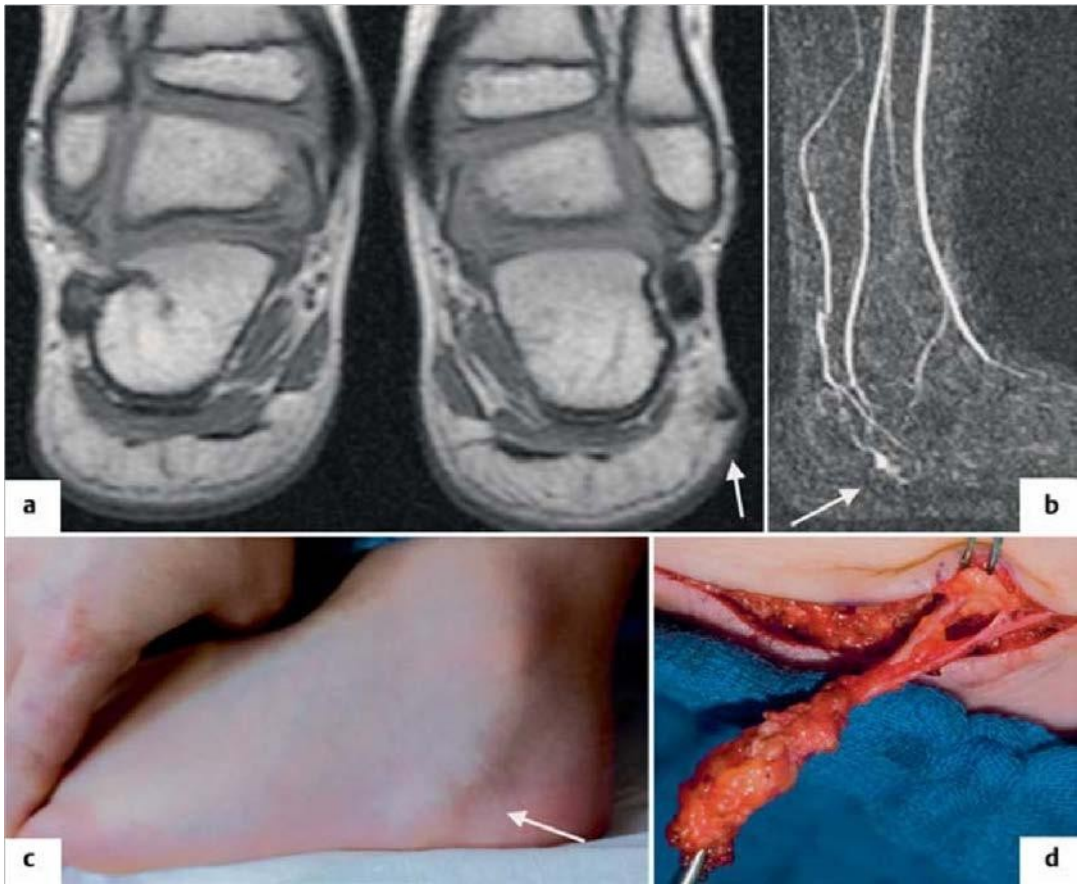

Figure 4 a,b,c,d. Child 8 years old with painful pulsating swell at the lateral edge of the heel (c), magnetic resonance imaging showed an arteriovenous malformations (a,b) which was surgically completely resected (d).

1.5. Diagnostics of vascular malformations

A number of investigations are needed for correct diagnosis of vascular malformations. First of all a good history and physical examination is needed, but also a number of noninvasive and invasive diagnostic tests. The aim of all these diagnostic procedures is to correctly define the type, localization and the hemodynamic characteristics of vascular malformation, in order to be able to make up a guideline schema for appropriate therapy and successful treatment of patients with vascular malformations.

The table 5 provides the overview of the most commonly used diagnostic techniques:

	Infatile Hemangioma	CM	VM	LM	AVM
Ultrasound／Doppler	+++	++	++	++	+++
Plain radiographs	-	-	++	-／+	+
MRT	++	-	+++	++ +	++
CT	+	-	+	+	+
Angio-CT	-	-	+	-	++
Lymphoscintigraphy	-	-	-	+	-
Biopsy	+	+	+	+	+
Angiographie	-	-	+	-	+++

Table 5. Diagnostic imaging devices, table modified from Enjolras et al. [23]

1.5.1. Radiography

Radiography has limited use for detecting vascular malformations, but it can help to show organomegaly, phleboliths and soft issue masses, and when vascular anomalies are located so deep that is difficult to detect them by physical examination [51,64]. Conventional radiological imaging plays a minor role in the diagnosis of vascular malformations, it is useful when there is a bone involvement and when calcifications in soft tissue can be detected [13].

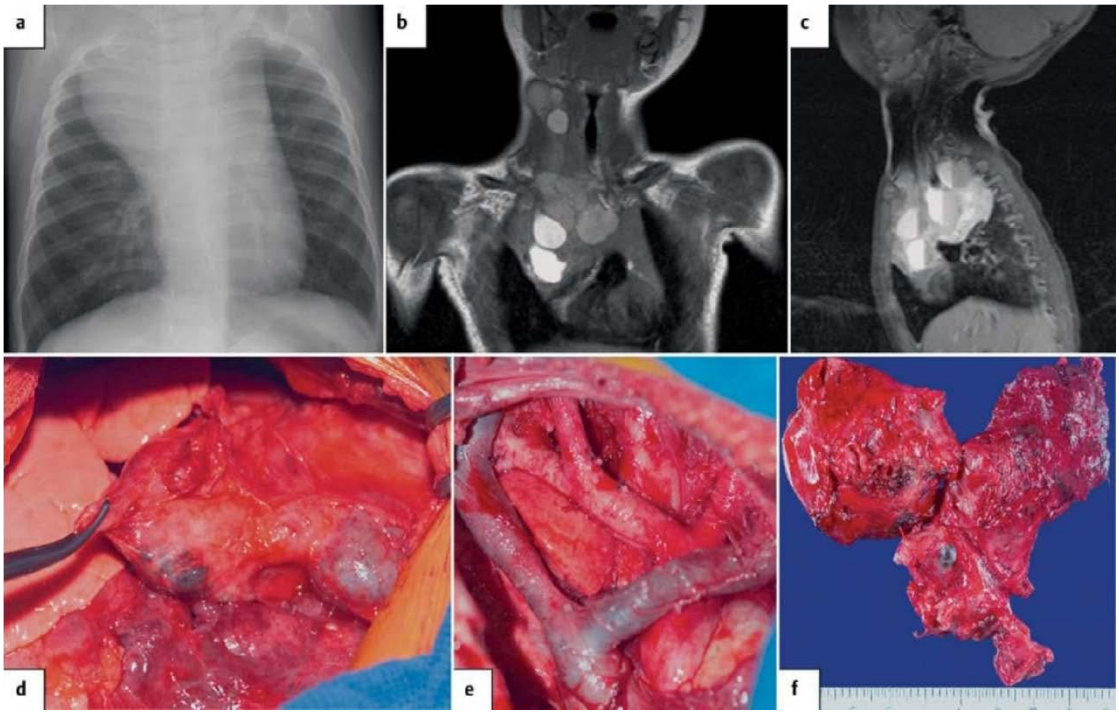

Figure 5 a,b,c,d,e,f. A child 9 months old with increasing shortness of breath, recurrent vomiting, livid discoloration and swelling of the left arm, (a) Chest X-Ray showed a massive widening of the upper mediastinum, (b,c) magnetic resonance imaging showed a mixed vascular malformation located in the entire upper mediastinum and the right side of the neck, (d,e,f) surgical resection was performed under strict protection of vital structures.

1.5.2. Ultrasonography

Ultrasonography is a noninvasive method, useful to differentiate a slow-flow from a high-flow lesion. It is ideal for children when examining superficial lesions, because it is painless, however in very young ages when children move a lot also this techniques needs to be done under some sedation of children to achieve correct results.

However, the ultrasound cannot penetrate bones or air, so we cannot get more information about deep pathological lesions in the thorax or in the gastrointestinal tract. Doppler Ultrasound can give qualitative data to define the type of vascular malformation and furthermore enables the distinction from Hemangioma's, by obtaining blood flow characteristics [13,66]. In venous malformations it is very important to detect segmental and long refluxes in the deep and superficial vein systems. In cases of lymphatic malformations ultrasound can detect edema and the presence of cysts [13,52].

Ultrasound can be extremely useful during percutaneous sclerotherapy and transarterial embolization, to follow the distribution of the sclerosing agents [53].

1.5.3. Computed Tomography CT and Magnetic Resonance Imaging MRI

CT and MRI give important results with a great value about anatomic extension of vascular malformations [13,60]. CT has some advantages, as it is better at revealing the calcification and skeletal or visceral involvement, but in practice CT is indicated when MRI cannot be used. MRI is more sensitive than CT in detecting venous malformations and their imaging manifestations shows: other internal body structure, fat infiltration and dilated veins associated soft-tissue masses. The best imaging modality for LM is MRI. Lymphatic channels disclose no enhancement after gadolinium infusion, and enhancement can be seen in the septa of the lymphatic cysts or in the presence of combined venous and lymphatic lesions [28].

MRI can provide important results about the quality of flow in the vessels showing a detailed vascular anatomy. Presence or absence of flow voids can differentiate high - flow from slow – flow lesions. MRI is the leading imaging modality in the diagnosis of vascular malformations. The main information is gained from a combinations of T1-weighted, fat-saturated T2-weighted and gradient-echo flow-weighted MR images [22,41,42].

The diagnostic variability for all types of vascular malformations in MRI are presented here:

Type of lesion	T1	T2	T1+Gd
Hemangioma	++	+ proliferating - involuted	+ proliferating visible flow voids - involuted
Lymphatic	+	++	- outline
Venous	+	++	++
High flow Vascular Malformations	-	-	-

Table 6. Diagnostic variability of vascular malformations in MRI

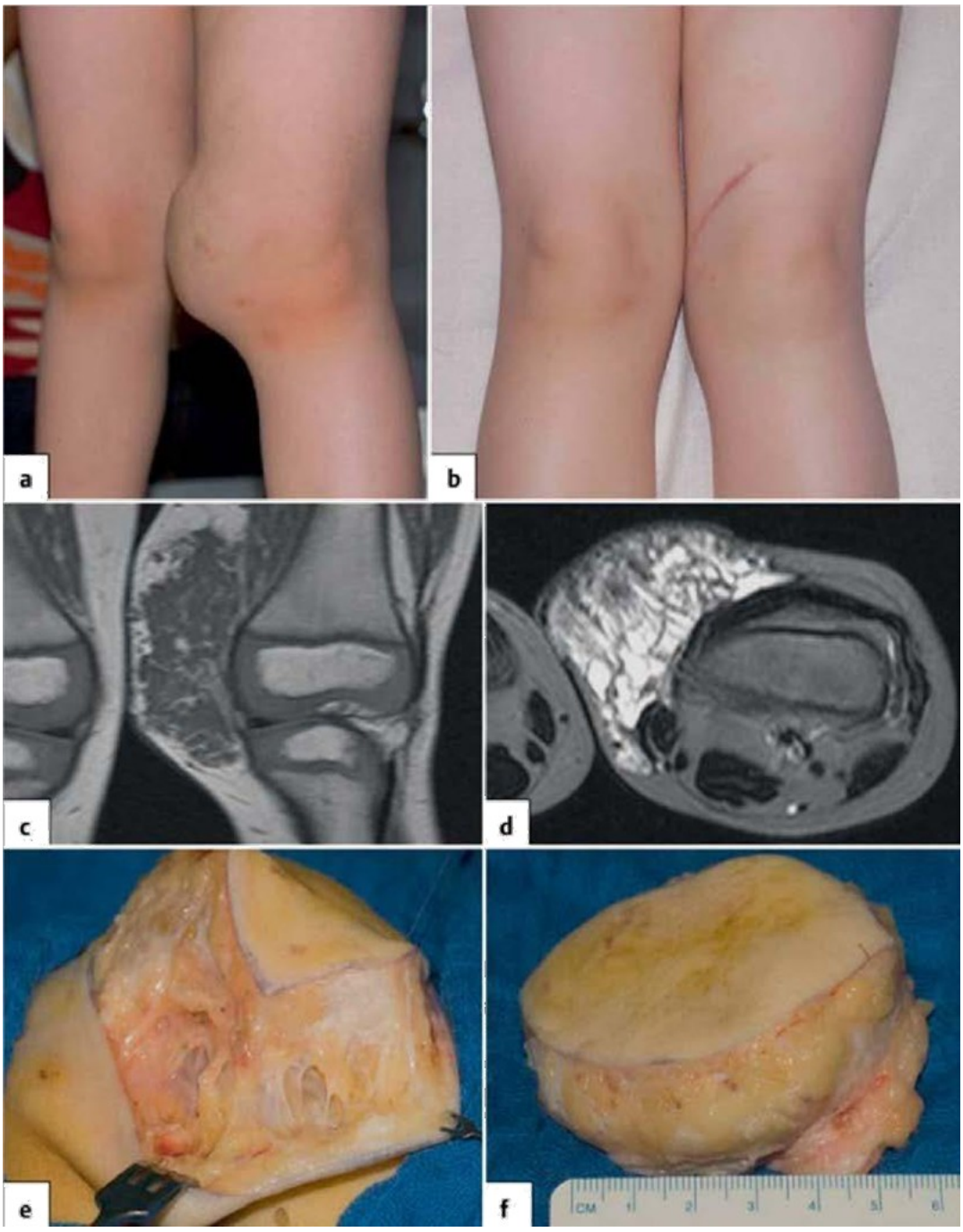

Figure 6 a,b,c,d,e,f. 3 years old child with microcystic lymphatic malformation at the in medial side of the left knee joint, (a) preoperative (b) postoperative, (c,d) magnetic resonance imaging of the expansion, (e) intraoperative image and (f) the specimen that has been resected.

1.5.4. Angiography / Phlebography

Angiography and phlebography may play a role in the preoperative assessment of the flow patterns of arterio-venous and/or venous malformations. These techniques may also play a role in the treatment of these lesions by means of sclerotherapy or embolization. However, angiography and/or phlebography are invasive examination methods, which if possible should be avoided in the diagnosis and treatment of children with vascular malformations, because of the high exposure to X-rays [24,40,43].

Arteriography is not a useful diagnostic procedure for slow-flow malformations. With this diagnostic method it is possible to define AVM and AVF. Venography and direct intralesional contrast injections are performed during an interventional treatment procedure for slow-flow vascular anomalies [35,39,43].

1.5.5. Biopsy / Histology

If the diagnosis is in question after medical history review, physical examination and diagnostic - radiological findings, a biopsy and histology may be needed to differentiate between different types of vascular malformations. In some cases immunochemistry analyses are needed to establish the correct diagnosis and decide about the possible treatment modalities [13].

1.6. Treatment of vascular malformations

For successful treatment of patients with congenital vascular malformations, it is important to remove the vascular malformations or the hemodynamic disturbance caused by them. The removal of vascular malformations may be or may not be radical, therefore it is necessary to create a clear treatment plan and define a goal for each treatment step. From all different treatment options the least invasive and simplest should be selected [13].

Based on the type of vascular malformation, treatment may include laser therapy, sclerotherapy, embolization and/or surgical resection. These procedures can be performed as a single treatment modality or in combination with each other [44].

1.6.1. Lasertherapy

The techniques of laser application in vascular malformations aim at destroying the pathologic vascular structure. In capillary malformations, laser treatments are the first choice of therapy, whereas in venous and lymphatic malformations laser therapy is a supplement to surgical excision and sclerotherapy [13,68]. Lasers can be used for photocoagulation, vaporization or excision procedures, like Nd:YAG 1064 nm laser (neodymium- yttrium- aluminum –garnet), KTP laser 532 nm (potassium–titanium–phosphate), diode laser 800– 980 nm, pulsed dye lasers 585 and 595 nm, argon laser 514 nm and carbon dioxide (CO_2) laser 10,600 nm [54].

The choice of laser types depends on the depth, the thickness and the kind of malformations, as the table below shows:

Superficial cutaneous	
Flat findings	Flash-lamp pumped dye laser
Teleangiectatic	findings Argon laser, KTP (potassium-tytanyl-phospate)
Tuberous findings	Pulsed Nd:YAG laser
Hyperkeratotic	findings CO2 laser
Intra- and subcutaneous to a depth of 1-15 mm	
Impression technique with bare fiber	
Transcutaneous Nd:YAG laser with ice-cube cooling	
Subcutaneous, voluminous up to a depth of 10 mm	
Nd: YAG laser interstitial or intraluminal	
Hollow organs, body cavities	
Nd: YAG laser endoscopic in air/water	

Table 7. Laser therapy treatment modalities [13]

Most vascular lesions require more than one laser treatment for optimal tissue healing and the laser technology has become so advanced and designed for deep penetration and strong absorption in hemoglobin, so that specific lesions can be eliminated [54].

1.6.2. Sclerotherapy / Embolization

Sclerotherapy is a form of nonsurgical intervention, used to treat venous malformations by injecting substances such as ethanol, polidocanol and sodium tetradecyl sulphate into the malformed vessels. For lymphatic malformations OK-432 (picibanil) is commonly used. Use of sclerotherapy in arteriovenous malformations is contraindicated, because the intra-arterial injections may produce extensive necrosis [13]. Injection of a sclerosing agent (liquid) into the area of venous deformity, produces a chemical irritation of the endothelial cells. Then a thrombus is produced and the vein is finally transformed into a fibrous thread that ultimately disappears [13].

Sclerotherapy is performed in lymphatic malformations when they are deep and difficult to access surgically with injection directly into the lesion leading to swelling, then fibrosis and regression of the cysts [56].

Embolotherapy with different materials such as coils, ethanol, sodium tetradecyl sulphate, cyanoacrylate, polyvinyl alcohol, microspheres and gelatin sponge, is often used for high flow vascular anomalies, for which it should be the first choice of treatment. Embolization is a procedure that prevents hemorrhaging, devitalizes structure by occluding its blood supply, thereby reducing the blood flow to an AVM. It is often helpful to combine embolotherapy with final surgical treatment [13,65].

The embolization material selectively obstructs and destroys the arteries, but it can lead to complications like skin ulceration, soft tissue necrosis, mucosal and nerve injury. Also complications of sclerotherapy may include swelling, skin and mucosal injury, infections and nerve injury [56,58,72].

1.6.3. Surgical treatment

Surgical treatment is a common method to treat vascular malformations. Dubois et al. [57] stated that after sclerotherapy when treatment is incomplete or when an aesthetic disfigurement requires correction, this can be done by surgical procedure. Often surgery can be applied alone as the only procedure, however it can also be applied together with sclerotherapy or embolization. The best option for venous malformations is treating them with surgical resection [13,61].

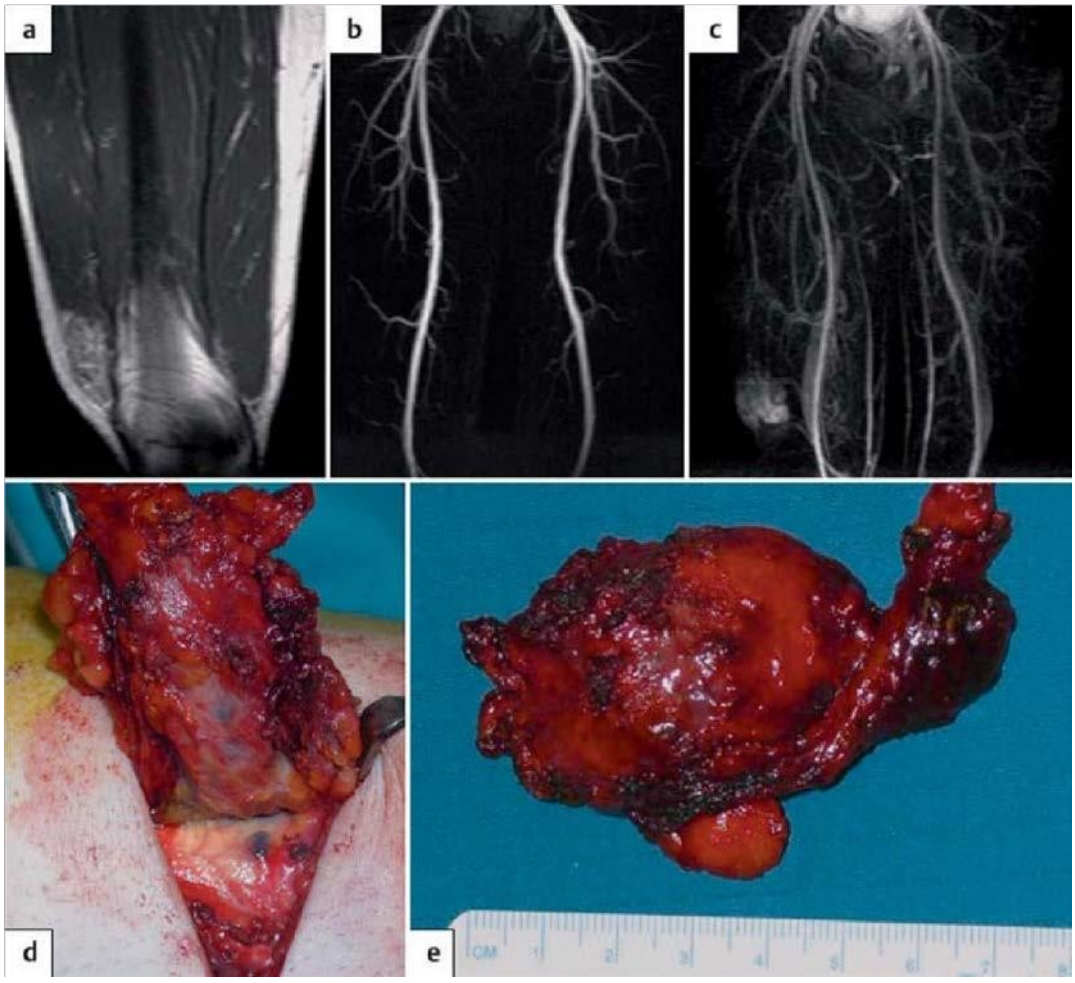

Figure 7 a,b,c,d,e. A 17 years old boy suffered many years with pain in the area of the right knee joint, (a,b,c) magnetic resonance imaging shows a large localized venous malformation, (d,e) surgical resection of the malformation was performed.

The vascular malformations may be difficult to treat by surgical resection when they are located deep and involve vital structures, such as in craniofacial region, pelvis or other visceral organs.

1.6.4. Non-operative treatment

Non-operative treatment methods used for treatment of vascular malformations are compression dressings, such as an elastic garment or bandage, physiotherapy, lymphatic drainage and anti-inflammatory therapies [41]. When a microcystic lymphatic malformation of the extremities or trunk cannot be completely resected, they are treated by non-operative methods. Venous malformations of the limbs are treated with elastic compressions stockings and with anticoagulants medication to reduce thrombosis [5].

Treatment modalities

For extratruncular and truncular Vascular Malformations, there are a number of treatment options: [13]

Treatment guidelines in extratruncular vascular malformations

Aim of the therapy	Operations technique	Indications
Resection of the malformation	1. Radical resection of the malformation 2. Radical resection of the malformation together with the surrounding tissues	Limited malformations with no infiltration of the surrounding tissues Small size malformations infiltrating surrounding tissues
Reduction of shunt flow	1. Transcatheter embolization 2. Percutaneous embolotherapy 3. Ligation of the afferent artery 4. Ligation of all collaterals of principal artery and vein 5. Ligation in two steps of two vessels in the leg or forearm followed by distal embolization	Extratruncular AV malformations which are not resectable because of dimension or localization Surgical treatment in these cases is replaced by endovascular treatment
Non conventional interventions	1. Tangential resection of involved tissues after positioning of a running suture over clamps	Partial resection of soft tissue infiltrating vascular malformations Indicated according to the size and localization of the malformation
Multidisciplinary treatment	1. Vascular, orthopedic, plastic Interventions	Interventions according to the localization and complications of the pathology
Combined approach	1. Embolotherapy + vascular interventions + conservative treatment	AV shunts which can cause difficulties in the surgical approach because of size or anatomical localization

Table 8. Treatment guidelines in extratruncular vascular malformations [13].

Treatment guidelines in truncular vascular malformations

Aim of the therapy	Operations technique	Indications
Vascular reconstruction	1. Vascular malformation resection and direct reconstruction of vessel patency	Central and peripheral malformations consisting of aneurysmatic dilatation or hypoplasia or congenital stenosis of veins and arteries
	2. Vascular malformation resection and graft interposition	
	3. Endograft placement	
	4. By-pass graft	
	5. Patch plasty	
	6. Membranotomy	
	7. Percutaneous dilatation of venous webs	
	8. Implantation of Denver shunt	Chylous reflux in lower limbs
Devascularization	1. Resection of pathologic veins	Superficial vein incompetence
	2. Resection of deeply located AV shunts	
	3. Resection of superficially located AV malformations together with efferent veins	AV shunts
	4. Trans catheter embolization	
	5. Ligation of leaking lymphatic vessels	Lymphatic reflux
Non conventional interventions	1. Resection of all collaterals of the embryonal vein (Belov I)	Marginal vein associated with aplasia of the deep venous system
	2. Rerouting of the blood flow from The superficial to the deeply veins (Belov II) system	Superficial venous ectasias associate with hypoplasia of the deep venous
	3. Resection of the marginal vein with the aim of Fogarty catheter placement (Loose I)	Marginal associated with a normal deep venous system
Multidisciplinary treatment	1. Vascular, orthopedic, plastic interventions localization	Interventions according to the and complications of the pathology
Combined approach	1. Embolotherapy + vascular Interventions + conservative treatment	AV shunts which can cause difficulties in the surgical approach because of size or anatomical localization

Table 9. Treatment guidelines in truncular vascular malformation [13].

2. MATERIALS AND METHODS

A retrospective study of 97 patients treated during the period of 01.01.1991 – 31.12.2010 was performed. All male and female children with vascular malformations, who have been treated at the Department of Pediatric and Adolescent Surgery in LKH Graz, were including into this study. During the acquisition of the data these parameters were analyzed: the discharge diagnosis, the clinical presentation, the results of conducted imaging, the histological findings, as well as the outcome after the operative or non-operative therapy.

Data were collected from the open MEDOCS (Medical Documentation and Communications System) and from the KIS system.

Data were typed into a sheet and descriptive statistical analysis were performed:

- gender : female or male;
- symptoms and signs: swelling, pain, cosmetic disturbance, impaired function, no symptoms, skin efflorescence;
- type of vascular malformation: lymphatic, venous, arteriovenous, capillary and combined;
- location: head and neck, trunk, upper extremities, lower extremities and generalized;
- imaging modalities: US, X-ray, MRI- MR-Angio, CT;
- histology results;
- treatments modalities: lasertherapy, sclerotherapy, embolization, partial
- resection, complete resection and non-operative therapy or combinations
- between them;
- recurrence after the treatment.

3. RESULTS

3.1. Gender distribution

From 97 studied patients with vascular malformations 52 (53.6%) were female and 45 (46.4%) were male. The gender distribution of females to males was 1.1: 1, as shown in Fig. 8.

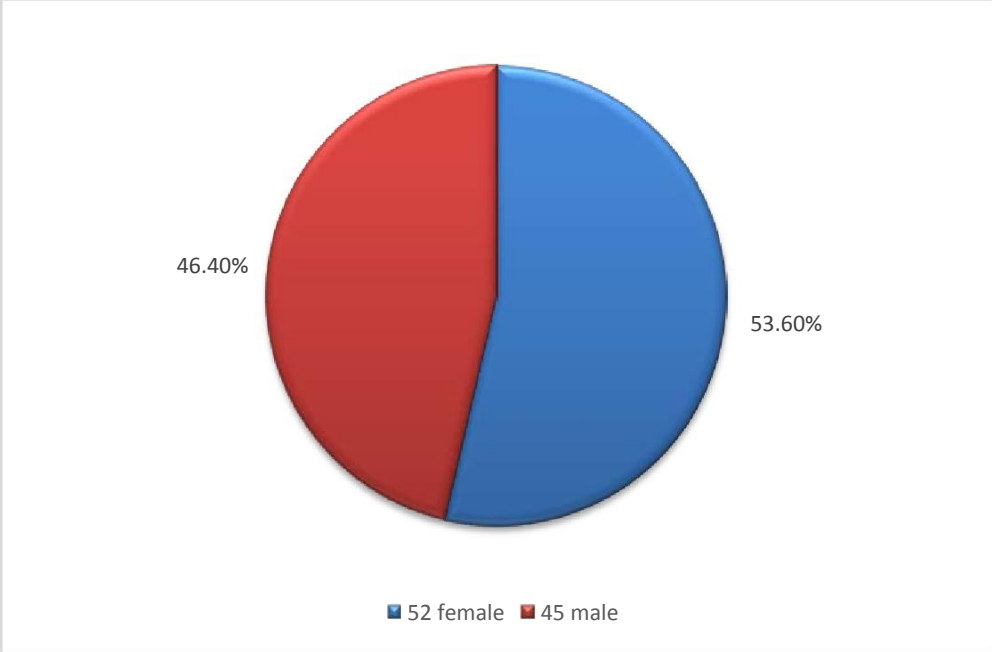

Figure 8. Gender distribution of all patients

3.2. Types of vascular malformations

From all 97 patients, the data that we retrieved on differentiating the type of vascular malformations, there were LM 37 (38.1%), VM 25 (25.7%), AVM 17 (17.5%), CM 5 (5.1%) and combined vascular malformations 13 (13.4%) cases.

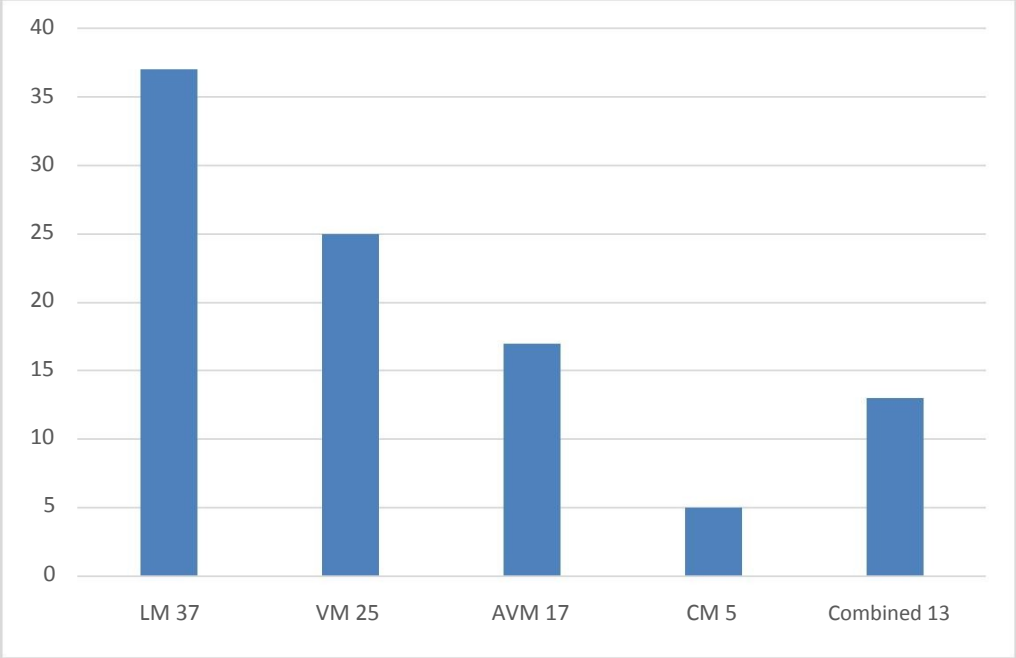

Figure 9. Types of vascular malformations from all 97 patients.

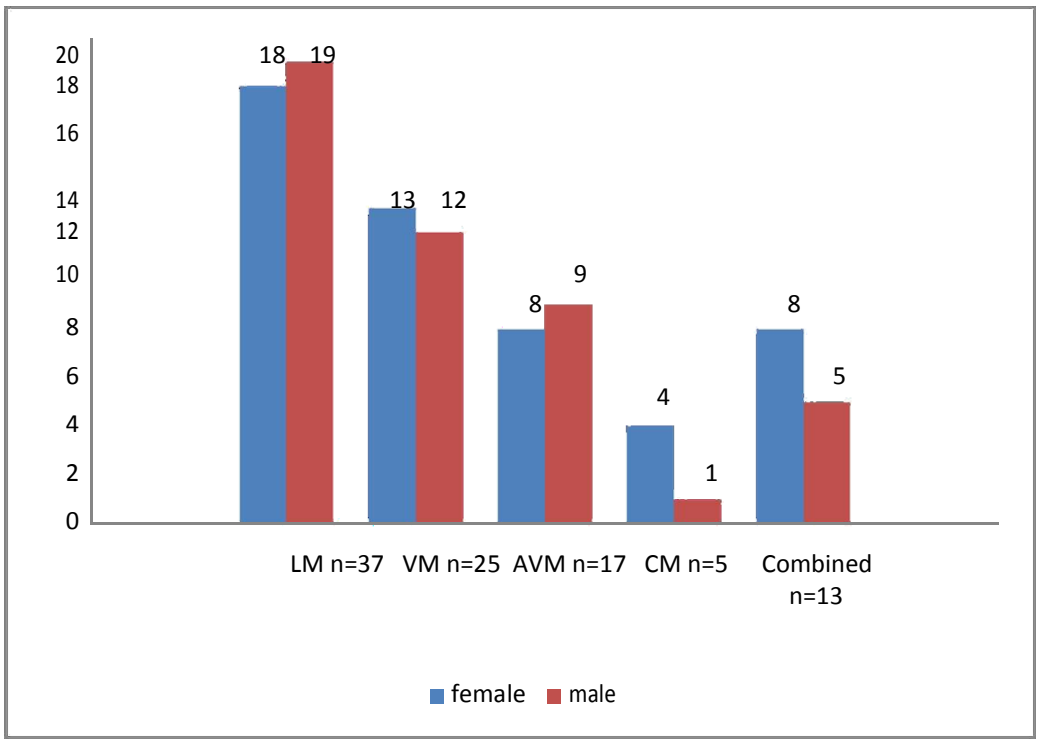

Figure 10 shows the gender distribution of our patients grouped in different vascular malformation types.

The largest number of investigated patients had lymphatic malformations, followed by venous malformations and a smaller numbers of patients had capillary malformations.

3.3. Location

The locations of the vascular malformations were in the head and neck in 21 patients (22%), trunk in 30 patients (31%), upper extremities in 16 patients (16%), lower extremities in 28 patients (29%) and generalized on more parts of body in two patients (2%).

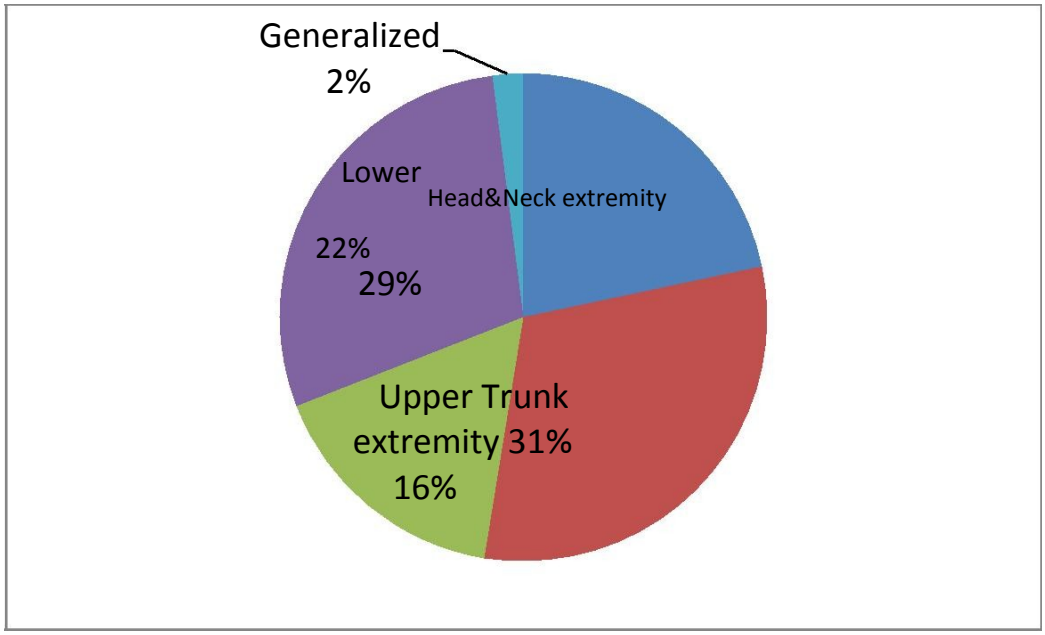

Figure 11. Anatomic distribution of vascular malformations in 97 patients

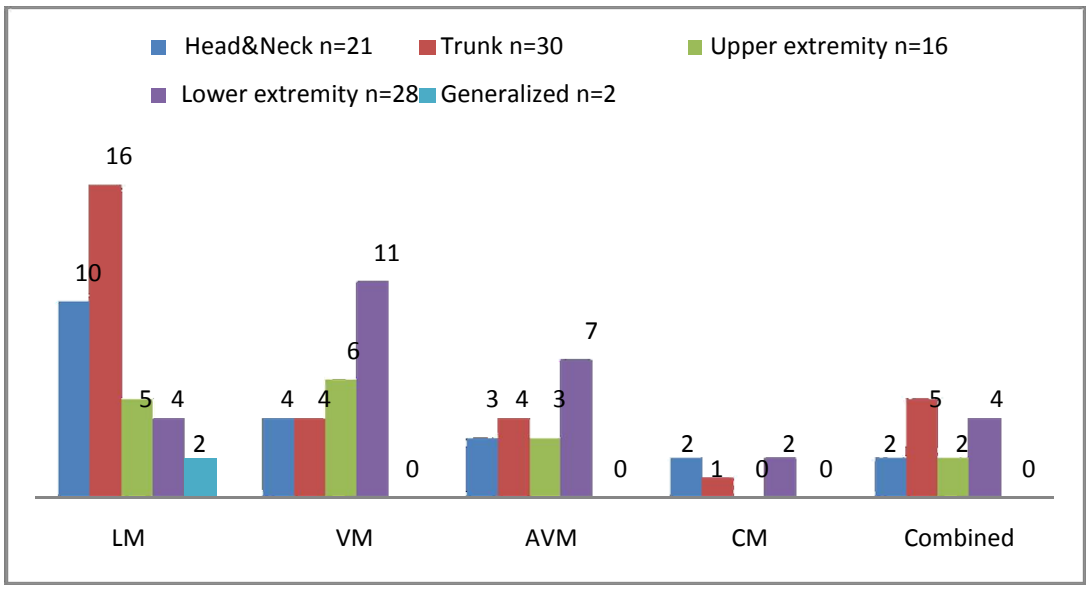

Figure 12. Locations by anatomic area and type

The most common localization of lymphatic malformation was in the trunk and head-neck region, followed by venous and arteriovenous malformations in the lower extremities.

3.4. Treatment indications

All of 97 patients with vascular malformations presented symptoms and signs as shown in the Fig.13. The main symptoms were swelling and pain. The other symptoms such as cosmetic disturbance, impaired function and skin changes were less frequent.

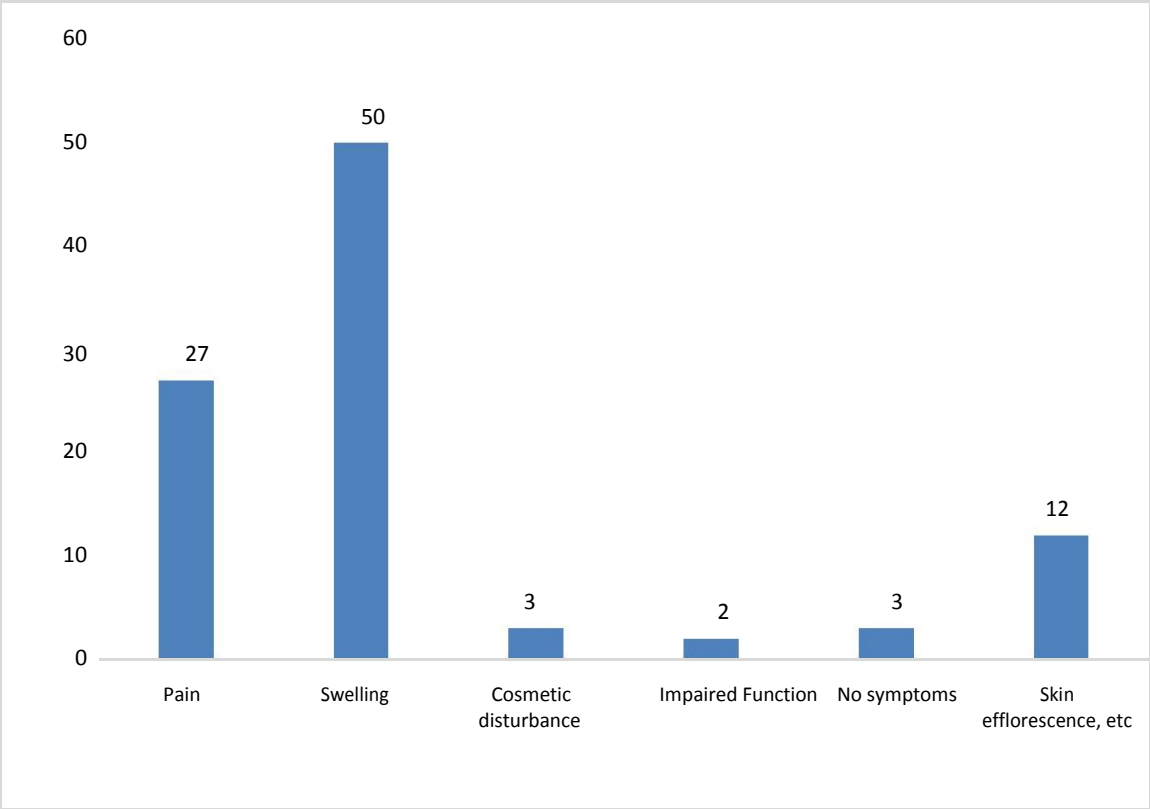

Figure 13. Summary of symptoms of all patients with vascular malformations

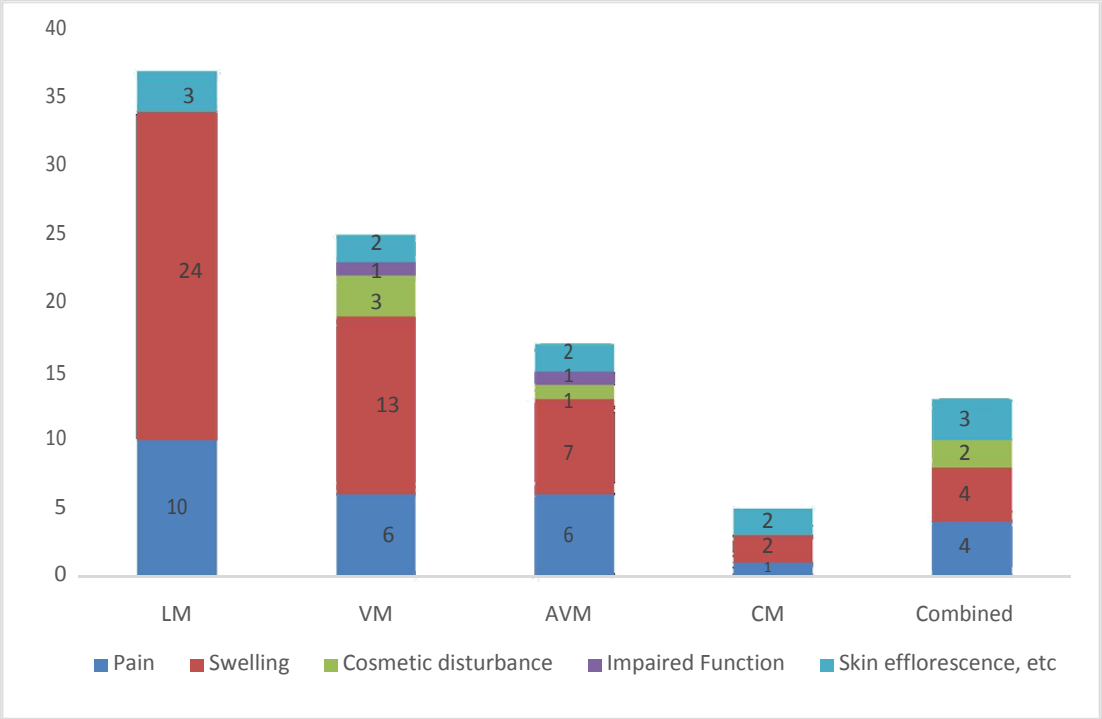

Figure 14. Treatment indications for LM, VM, AVM, CM and Combined malformations

As we can see from the Fig.14 the two most common early signs and complications of lymphatic malformations were swelling and pain. This was the same also for all other vascular malformations. The rarest treatment indications were cosmetic disturbance, skin efflorescence and impaired function.

3.5. Diagnostic modalities of vascular malformations

The clinical diagnosis has been further evaluated by plain films (X-rays), ultrasonography (US), magnetic resonance tomography/angiography (MRT-MRA) and computed tomography (CT). The summary of various imaging modalities is given in figure 15.

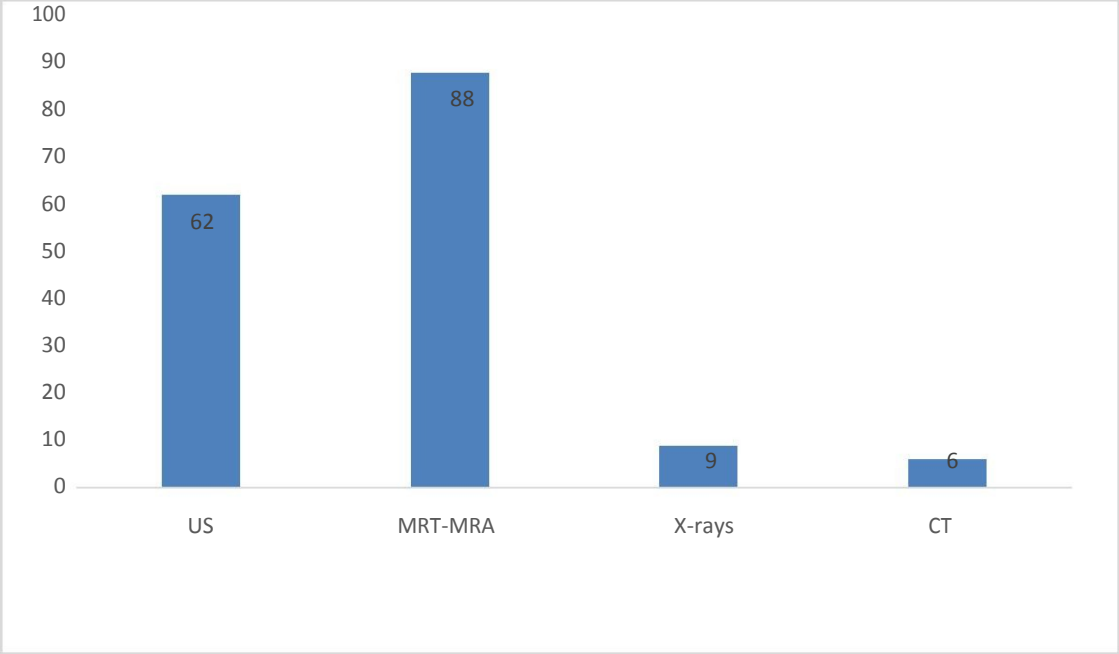

Figure 15. Imaging modalities of all vascular malformations

From Fig.15 we can see that the most useful diagnostic procedures are magnetic resonance tomography and ultrasonography. For other cases, where it was more difficult to differentiate between different vascular malformations, it was necessary to use also other imaging methods.

Table 10 shows the variety of imaging techniques used in the frame of the evaluation process to diagnose various vascular malformations.

	US	MRT	MRA	X-rays	CT	No need for imaging
LM	17	20	1	1	1	
VM	14	13	9	3	3	1
AVM	20	15	3	1	2	
CM	1	3		1		1
Combined	6	6	4	2		

Table 10. Imaging modalities for all patients with vascular malformations

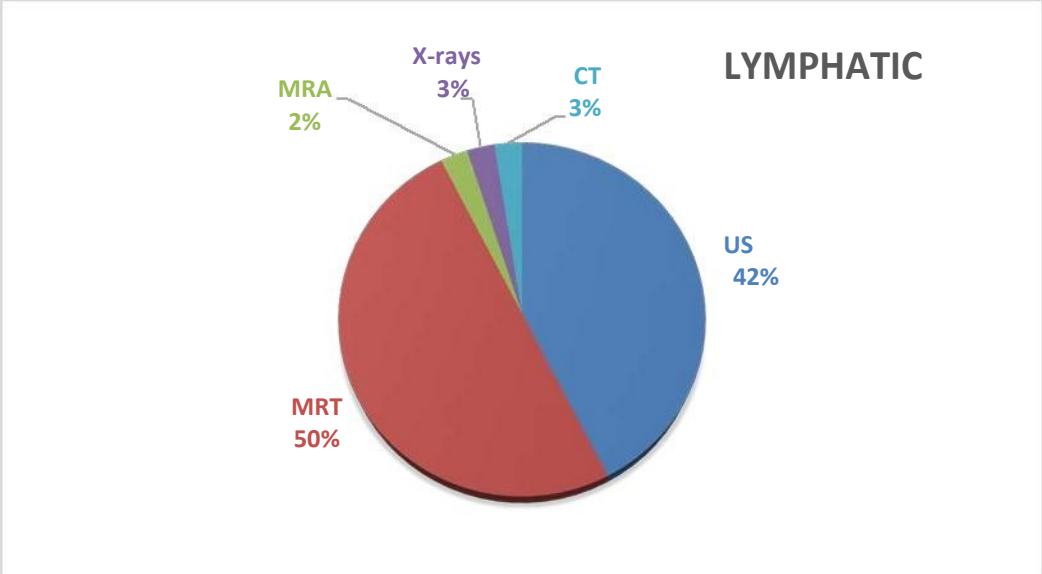

Figure 16. Diagnostic modalities for patients with lymphatic malformations

Figure 16 shows that in the majority of cases with lymphatic malformations there is a need for a MRT in order to get the correct diagnosis.

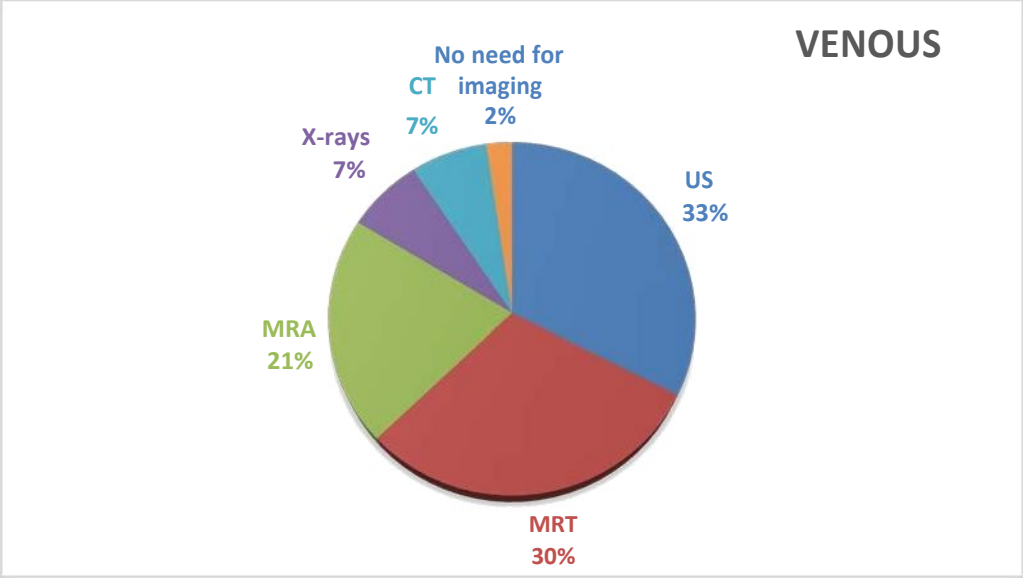

Figure 17. Diagnostic modalities for patients with venous malformations

In patients with venous malformations it was necessary to perform various diagnostic methods. However, also in VMs the best diagnostic option is magnetic resonance tomography – angiography (MRT-MRA) followed by ultrasonography (US). In complex cases it was important to perform combinations with other imaging modalities such as CT and X-rays. In one case there was no need for any diagnostic methods after analysis of the history of the patient and his clinical presentation.

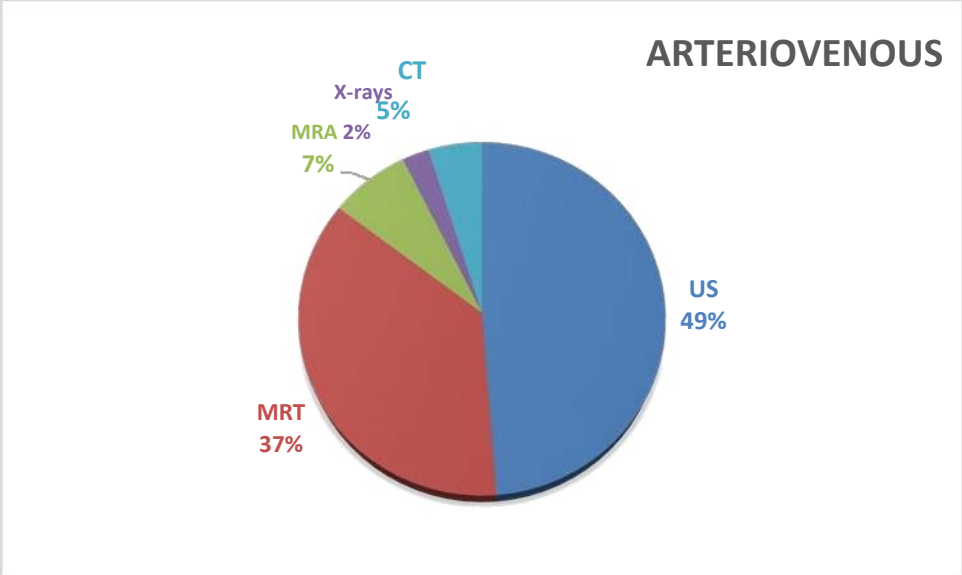

Figure 18. Diagnostic modalities for patients with arteriovenous malformations

The figure 18 shows that the two of the most frequently used imaging modalities for detection of AVMs are MRT and US, but CT with X-rays may also be helpful. New imaging technologies offer the most accurate pictures and best diagnostic information of blood vessel structure.

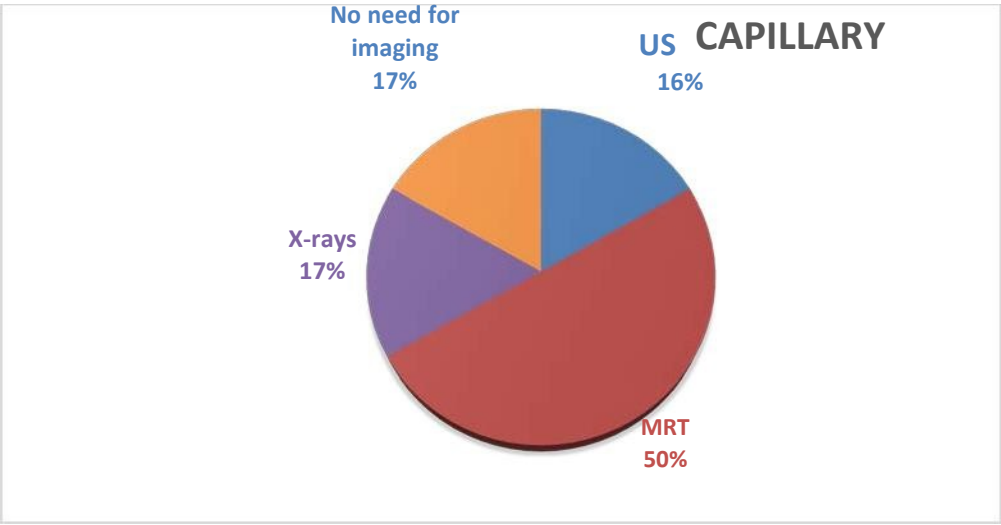

Figure 19. Diagnostic modalities for patients with capillary malformations

Figure 19 shows that in 2 cases with capillary malformations there was a need for a MRT in order to get the correct diagnosis. Such imaging modalities must be performed if there is any suspicion of syndromes like/ or example Sturge-Werber-Syndrome. In one patient with capillary malformation no imaging was needed.

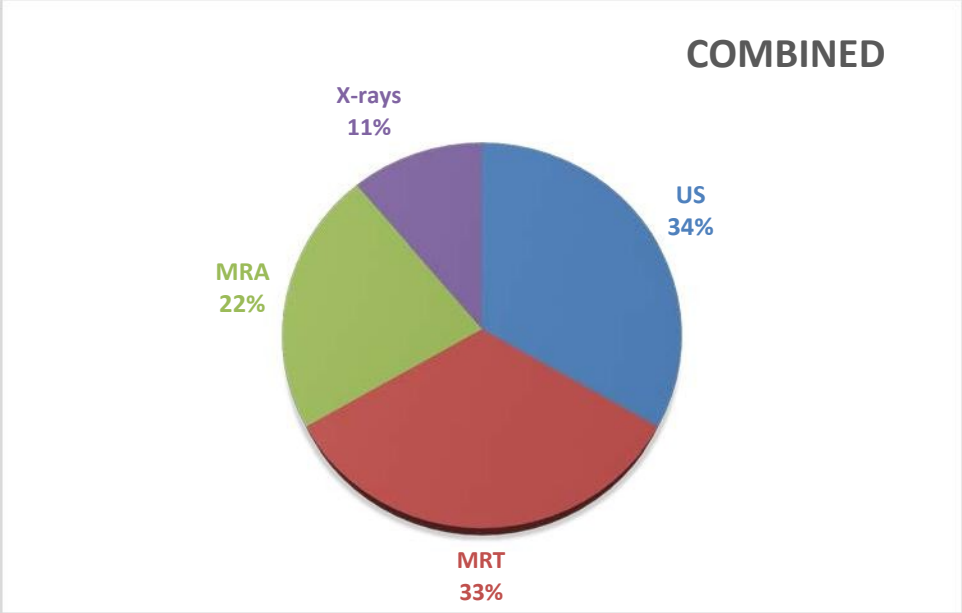

Figure 20. Diagnostic modalities for patients with combined malformations

The figure 20 shows that the most important imaging techniques for combined malformations were US and MRT-MRA.

Histology

It was necessary to clarify and confirm the exact diagnosis for all 97 patients with vascular malformations. In 58 cases an operative specimen was obtained and in 39 cases no histological examinations were performed since no specimen was obtained.

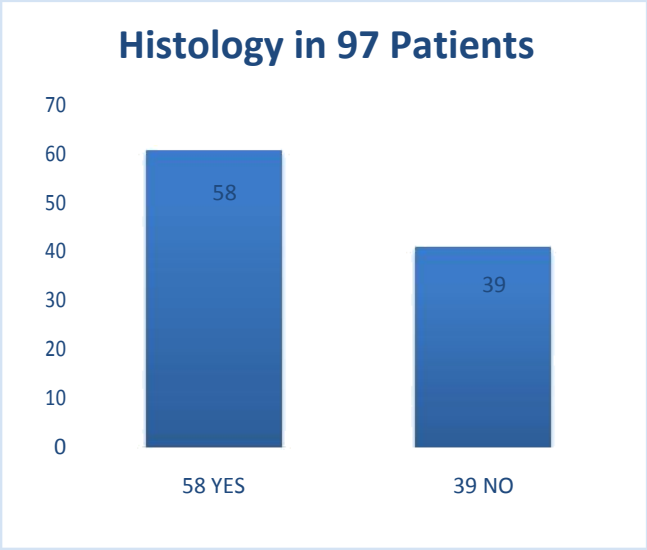

Figure 21. Histological examinations

3.6. Treatment modalities of vascular malformations

The figure 22 shows an overview of the performed treatment modalities.

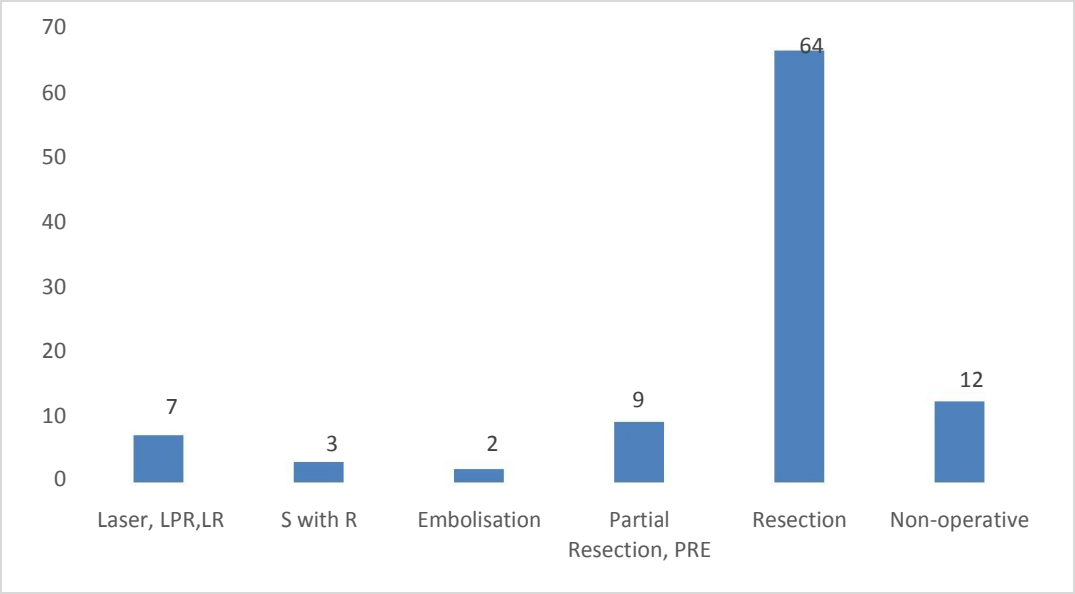

Figure 22. Treatment modalities of all 97 patients, LPR (laser with partial resection), LR (laser with resection), SR (sclerotherapy with resection), PRE (partial resection after embolization).

The most common treatment type was surgical resection represented with 66%. This therapy has taken first option place and was conducted on all vascular malformations. Other treatment modalities were partial resection alone or after embolization, non-operative therapy, laser therapy alone or in combinations with sclerotherapy and partial or total resection. In two cases embolizations were performed.

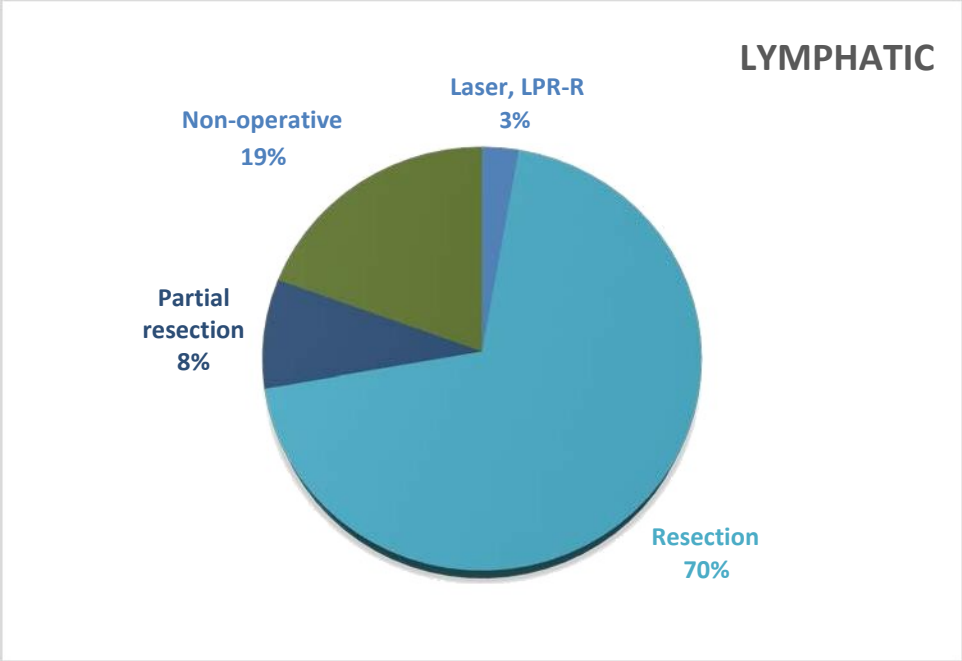

Figure 23. Treatment modalities by lymphatic malformations, LPR-R (lasertherapy with partial or total resection).

In 37 patients with lymphatic malformations, different treatment methods were performed. The main therapy was surgical resection, followed by non-operative therapy and only a few cases were treated with partial resection or laser therapy.

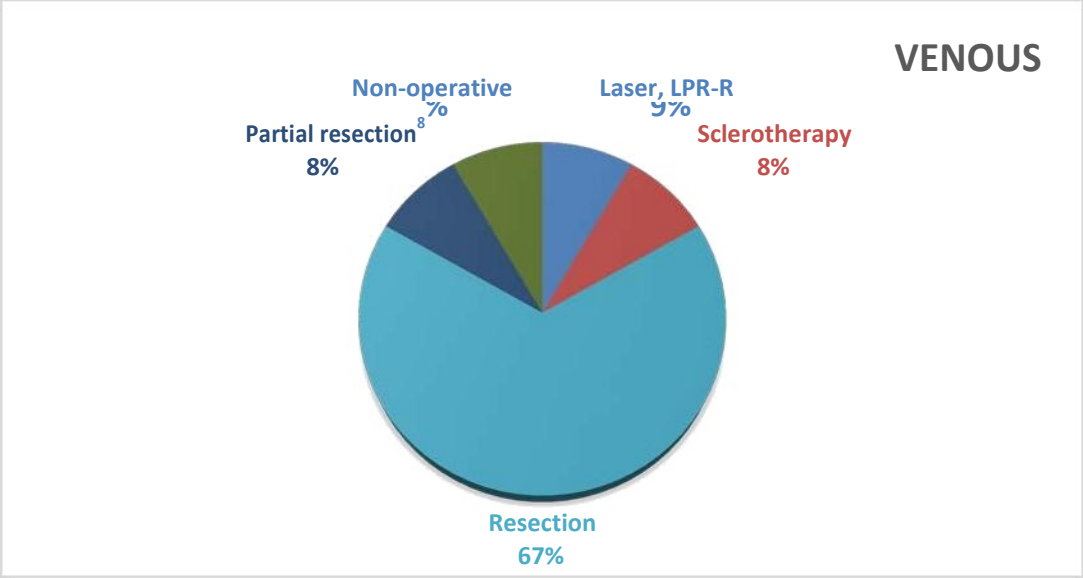

Figure 24. Treatment modalities for venous malformations LPR-R (lasertherapy with partial or total resection).

In 25 patients with venous malformations, different treatment methods were performed. The main therapy was surgical resection, followed by lasertherapy alone or with partial/or-total resection.

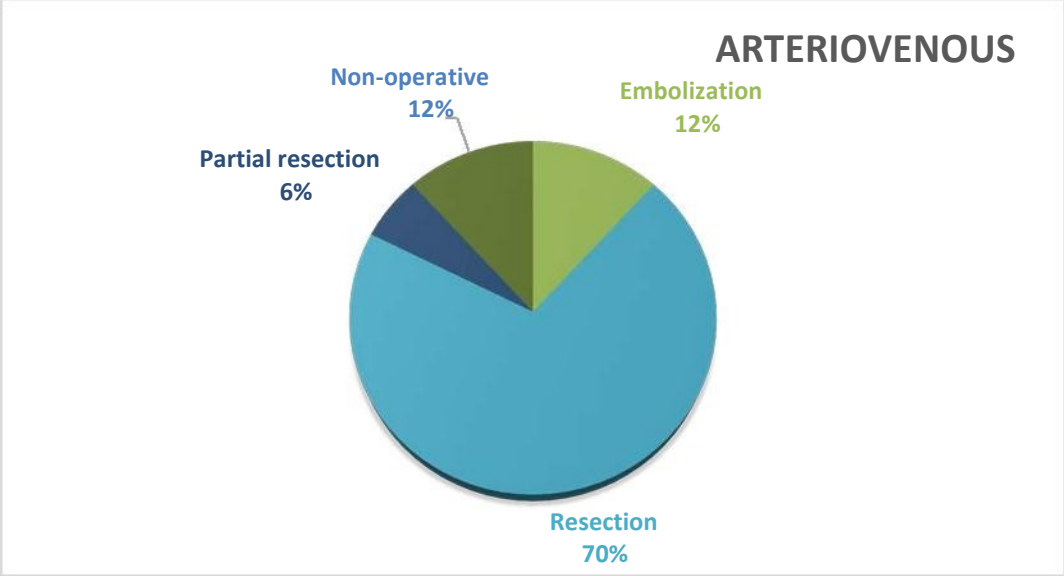

Figure 25. Treatment modalities for arteriovenous malformations

In 17 patients with arteriovenous malformations, different treatment methods were performed. The main was surgical resection, followed by non-operative therapy and embolization procedure. One case was treated with partial resection.

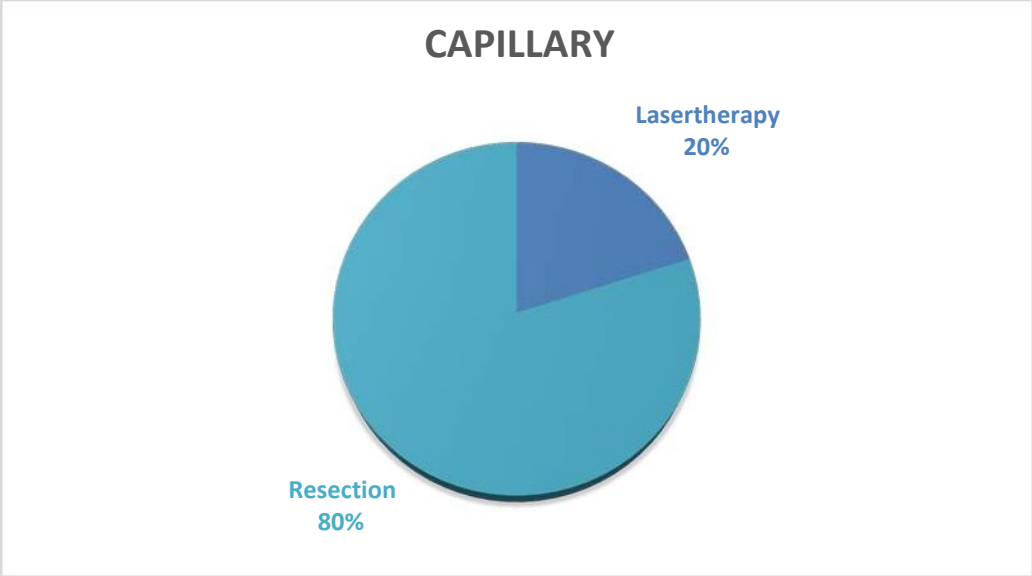

Figure 26. Treatment modalities by capillary malformations

In 4 patients with capillary malformations, surgical resection was performed and lasertherapy in one patient.

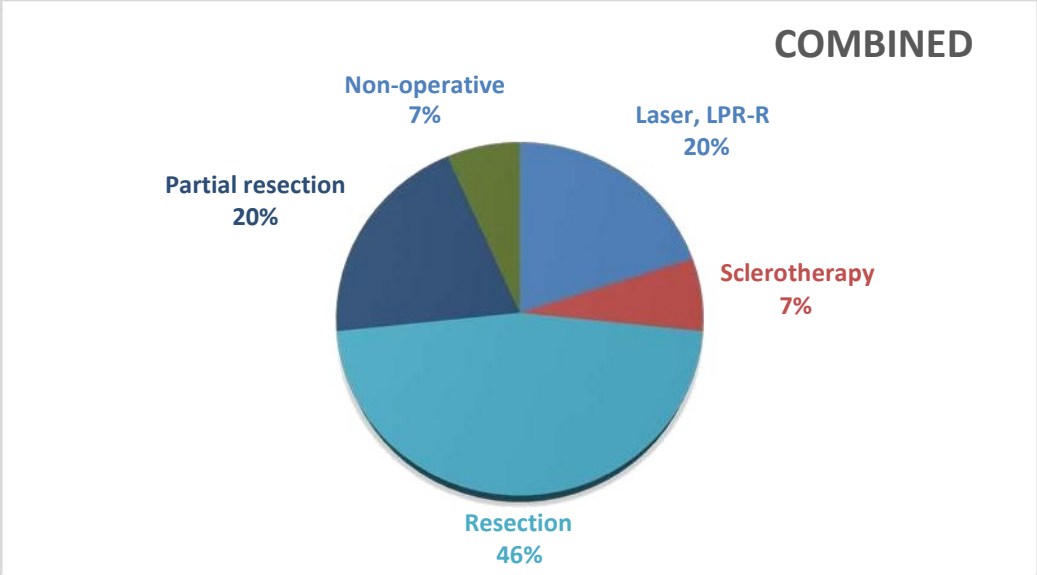

Figure 27. Treatment modalities for combined malformations, LPR-R (lasertherapy with partial or total resection).

The figure 27 shows that the treatment modalities in patients with combined malformations were surgical resection, followed by partial resection and lasertherapy. In few cases it was necessary to perform non-operative therapy and sclerotherapy.

3.7. Recurrence

According to the follow-up data 78% of cases were successfully treated. After they were treated, 22% of patients got recurrence, and another treatment was necessary.

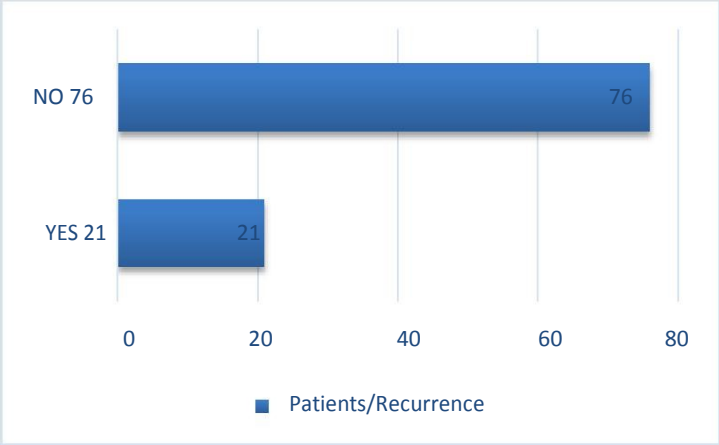

Figure 28. Recurrence after the treatment

4. DISCUSSION

Vascular malformations present a complex group of inborn errors of vasculogenesis and/or angiogenesis which in grave cases can be suspected prenatally by ultrasound and/or prenatal MRI. Under the term "vascular anomalies" all vascular diseases, i.e. various vascular tumors and all various vascular malformations have been grouped. While vascular tumors may have different timing of appearance from the prenatal, over the postnatal period, up to old age, vascular malformations are usually present at birth, and may seldom occur later in life such as during posttraumatic repair of tissues after injuries, or after surgical intervention for treatment purposes like dialysis. Though the current classification of vascular anomalies has been proposed in the early 80-ties and was accepted by the ISSVA in the mid 90-ties, in the literature we often find that the nomenclature and classification of vascular malformations is not used uniformly, and even today we can often see quite confusion when using terms for these lesions. First of all it is important to differentiate vascular tumors, from vascular malformations. The congenital vascular malformations are divided into slow-flow malformations (capillary, lymphatic, venous, or combined), and high-flow malformations (pure arterial, arteriovenous fistulas, arteriovenous malformations). Besides these there is further a group of complex combined syndromes with all their varieties, which not only have a component of a vascular malformation, but also other pathologic findings like: epilepsy, lipomas, overgrowth, etc. [5,6,13,22,23,40].

The aim of the present study was to analyze retrospectively the outcome of all patients with vascular anomalies hospitalized and treated at the Dept. of Pediatric and Adolescent Surgery in Graz over the 20 years period.

The present study found that the gender distribution of females to males was 1.1:1 which is quite equal and corresponds to the data for gender distribution of patients with vascular malformations found in the literature

[13,37,44,70]. The data that were retrieved on various types of vascular malformations showed that the incidence of patients with LM among all patients with vascular malformations was 38.1%, those with VM was 25.7%, with AVM 17.5%, CM 5.1%. Combined vascular malformations were found in 13.4% of all patients.

Concerning their extension and growth pattern vascular malformations may be localized or infiltrative. They can furthermore occur anywhere in the body, but their most common occurrence is especially in the head and neck region. Anatomic distributions of these lesions in the present study were in the neck in 22%, trunk in 31%, and all together in the upper and lower extremities in 45% of all patients. Only in a few patients and this was usually the cases in complex combined forms or syndromes vascular malformations were found at the same time in more regions of the body.
The most common symptoms in patients with congenital vascular malformations were swelling and pain. Other symptoms such as cosmetic disturbance, skin changes and impaired function were less frequent in the patients in our study group. These were however very common in patients with large LM in the head and neck regions.

In the present study the clinical diagnosis has been further evaluated by various imaging modalities. The main imaging techniques performed were magnetic resonance imaging with angiography (MRI-MRA) in 53% of patients and ultrasonography (US) in 38% of patients. Other imaging modalities such as plain x-ray films or CT imaging were used in patients when more detailed imaging of the lesions was necessary and osseous involvement was suspected. Radiography helps to show organomegaly, osseous destruction and phleboliths, and CT may provide further information about the exact vascularization, and shows better calcifications and the skeletal involvement [13,26,42,47,57].

The preferred therapies in the present study were complete resection, partial resection, sclerotherapy, embolization, lasertherapy, non-operative therapy, or combinations between them. For successful treatment of vascular malformations it is necessary to be able to use all available

treatment modalities alone or in combination, with the main goal to completely remove the lesions without damaging the function – in this way the recurrence of these lesions can be avoided. Surgical resection was performed in 66% of all patients partial resection in 9%, lasertherapy alone and in combination with other modalities in 7%, sclerotherapy in 3%, embolization in 2% and conservative therapy in 13% of patients. The first line of treatment for CM was lasertherapy and/or surgical resection. VMs are more difficult to treat and usually it is necessary to apply more treatment modalities like non-operative therapies, or sclerotherapy often associated with surgical resection. For localized LMs best therapeutic option seems to be the surgical resection, however in cases with infiltrative growth or microcystic pattern combinations of treatment with sclerotherapy and non-operative treatment modalities are common. For AVMs the first treatment option is embolization followed by surgical resection.

The choice of the therapy has certainly to deal with the nature of the surgical Department the study was carried out at. Probably the choice of the therapy would have been different if the study would have been performed at the Dermatology Department, but also the distribution of various vascular malformations would have been different, because at the Dermatology Department probably more patients with CM are treated then on a surgical Department. The surgical resection is a very useful treatment method in cases when the vascular malformations are localized and do not involve vital structures like nerves or any other functionally important organs. When vascular malformations are localized deep and involve vital structures it is impossible to remove them by surgical resection without damaging the function. Therefore, in such cases it is necessary to use other treatment modalities such as sclerotherapy or embolotherapy and in some cases also lasertherapy. Sclerosing agents commonly used are ethanol, OK-432 and bleomycin. These are effective because they lead to endothelial damage and/or thrombosis of vascular spaces in the malformed vascular tissues [13,41,49,58,65].

5. CONCLUSIONS

The present study confirms that the complexity of the diagnosis and treatment options of vascular malformations need a close interdisciplinary cooperation of experts from different disciplines, to provide the best possible care for these patients. Through the collaboration of experts from different fields such as pediatric surgeons, plastic surgeons, vascular surgeons, oral and maxillofacial surgeons, orthopedic surgeons, pediatricians, dermatologists, radiologist, ear-nose-throat surgeons, ophthalmologists and others, an exact diagnosis and best treatment options can be found. The type and localization of vascular malformations usually determines the urgency of an intervention and the method of choice.

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