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TO USE OR NOT TO USE: APPLICABILITY OF MURRAY'S LAW IN NUMERICAL MODELING OF VASCULAR DICHOTOMIES OF KIDNEYS

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DISCLOSURE

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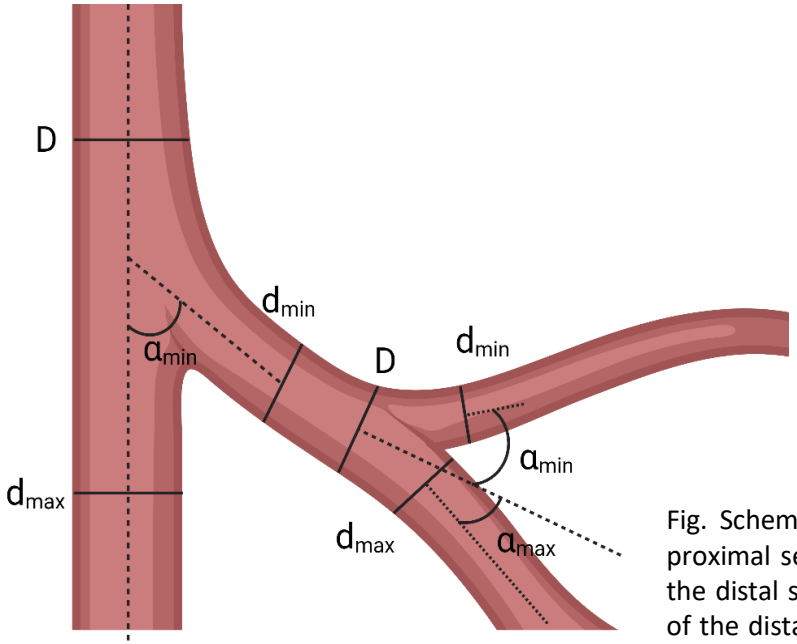
INTRODUCTION

In 1926, the English physiologist Murray C. D., based on the so-called "Roux rules", proposed equations that allow to calculate the angles of arterial dichotomy, knowing the values of the internal diameters of the arteries that form it. There are works that both confirm and refute the position of the theory (Murray's law) to the results of morphometry of real arterial beds.

The aim of the study is to analyze the applicability of the equations of Murray C. D. for calculating the angles of dichotomies of the intraorgan arterial and venous vessels of the human kidney.



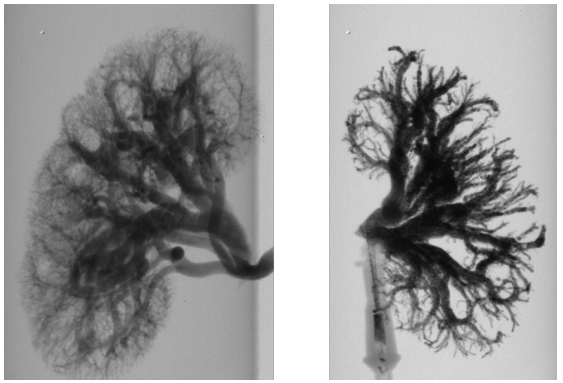


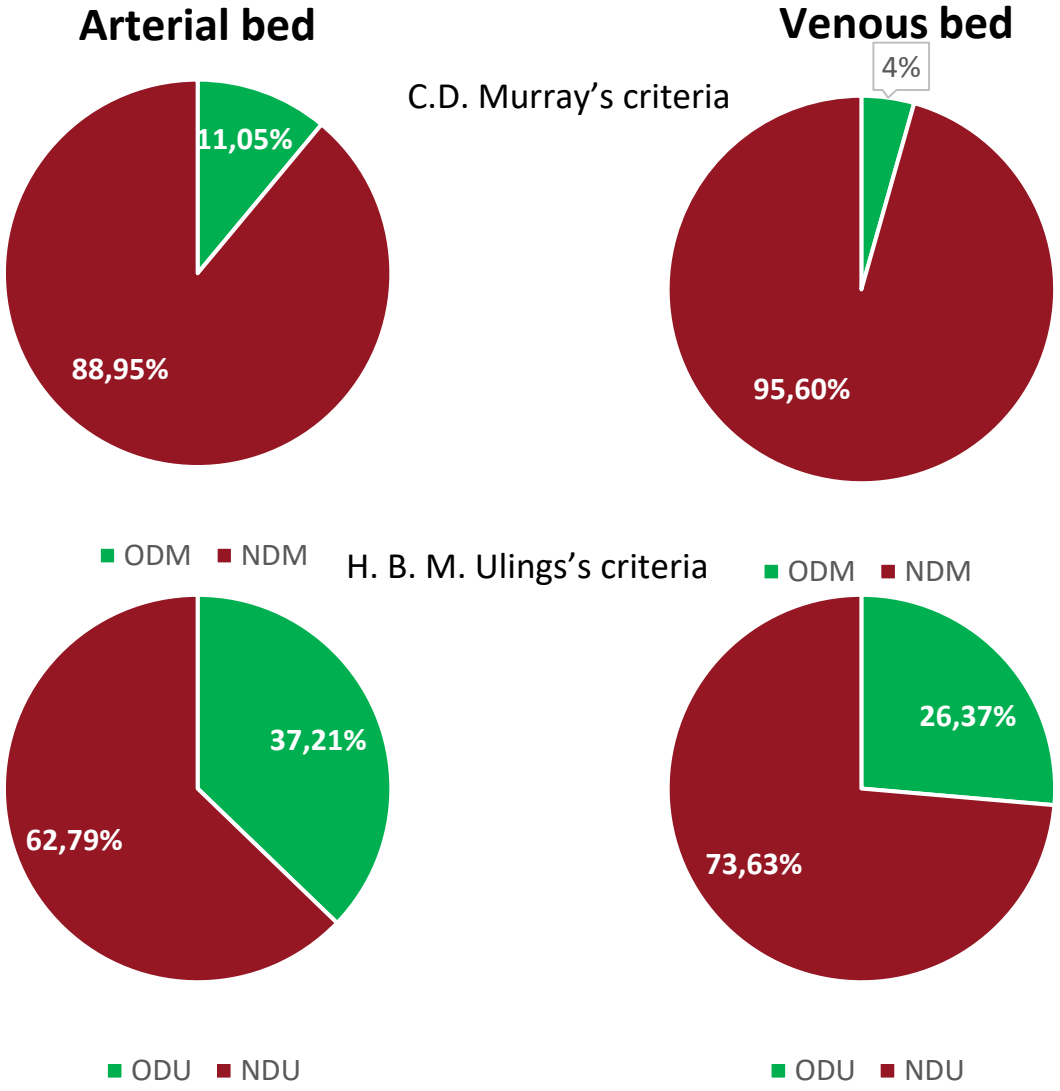
Fig. Arterial and venous bed of the kidney. CT-scan

Fig. Scheme of vascular (arterial and venous) dichotomy, where D is the proximal segment, d_{max} is the distal segment with a large diameter, d_{min} is the distal segment with a smaller diameter, α_{max} is the angle of divergence of the distal segment with a larger diameter from the proximal one, α_{min} is the angle of divergence of the smaller distal segment from the proximal.

Materials and methods

The intraorgan vascular beds of the kidneys (arteries and veins) were examined, visualized at autopsy in people (age from 36 to 74 years; 9 males, 8 females) who died from pathology that practically did not change the vascular bed of the kidney (asphyxia).

C.D. Murray's criteria



Results

Values of morphometric and calculated angles α_{max} and α_{min} of dichotomies

	Arterial bed			Venous bed		
	Morphometric	Calculated	p	Morphometric	Calculated	p
α_{max},° Me (CI)	28,0 (20,0; 30,0)	29,7 (27,3; 33,9)	0,61	18,1 (14,1; 29,7)	29,7 (22,4; 32,7)	0,64
α_{min},° Me (CI)	49,5 (42,1; 53,0)	55,4 (53,3; 56,9)	0,007	26 (20,3; 37,4)	54,5 (52,7; 56,9)	0,005

Note: α_{max} is the angle of divergence of the larger distal segment from the proximal (°), α_{min} is the angle of divergence of the smaller distal segment from the proximal (°), p is the level of significance of the differences (Mann-Whitney U test).

The α_{min} values of "optimal" (ODU) and "non-optimal" (NDU) in accordance with the H. B. M. Ulings's criteria

	Dichotomy groups according to H. B. M. Ulings's criteria					
	Arterial bed			Venous bed		
	ODU	NDU	p	ODU	NDU	p
α_{min},° (morphometric) Me (CI)	51 (45;70)	45 (35;53)	0,042	22,6 (17.2;40)	27 (20,3;37,8)	0,748
α_{min},° (calculated) Me (CI)	62,5 (55,4;66,2)	55,4 (53,3;58,0)	0,004	55,3 (47,1;61,5)	55 (52,7;57,9)	0,626
p	0,360	0,006		0,0001	0,0001	

Note: α_{min} is the angle of divergence of the smaller distal segment from the proximal segment (°), p is the level of significance of the differences (Mann-Whitney U test).

The α_{min} values of "optimal" (ODM) and "non-optimal" (NDM) in accordance with the C.D. Murray's criteria

	Dichotomy groups according to C.D. Murray's criteria					
	Arterial bed			Venous bed		
	ODM	NDM	p	ODM	NDM	p
α_{min},° (morphometric) Me (CI)	34 (26; 58)	49.5 (42,9; 53)	0,22	15,4 (0;60)	27 (20.3;37.8)	0,440
α_{min},° (calculated) Me (CI)	49,8 (45,1;52,7)	55,9 (55,2; 60,6)	0,003	45,1 (41,5;45,1)	56,9 (52.7;58.4)	0,047
p	0,271	0,005		0,343	0,0001	

Note: α_{min} is the angle of divergence of the smaller distal segment from the proximal segment (°), p is the level of significance of the differences (Mann-Whitney U test).

α_{min} of structurally different types of dichotomies

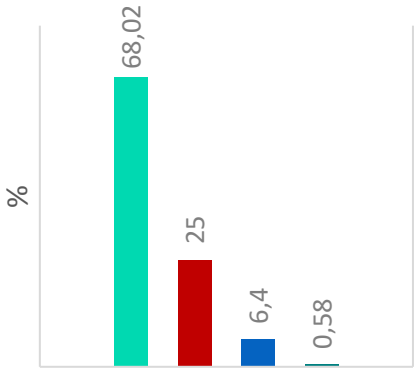
	Structurally different types of dichotomy							
	Arterial bed				Venous bed			
	1	2	3	p*	1	2	3	p*
α_{min},° (morphometric) Me (CI)	40 (34;50)	60 (50;77)	32 (2;47,5)	0,0001	26 (17,9;38)	32 (24;40)	32.65 (5;74)	0,134
α_{min},° (calculated) Me (CI)	55,4 (53.3;58.2)	59,2 (55;65,7)	43,6 (32,7;53,3)	0,008	56,9 (54,5;59,3)	53,6 (47,5;57,9)	39,1 (29,7;73)	0,021
p	0,0001	0,158	0,193		0.0001	0.0001	1.0	

Note: α_{min} - smaller angle of divergence of the distal segment of proximal (°), p * is the level of significance of differences (Kruskal-Wallis test), p is the level of significance of differences (Mann-Whitney U test).

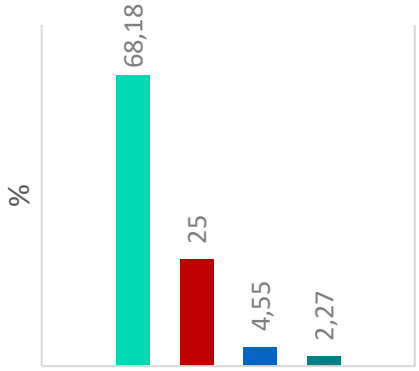
Conclusion

Distribution by types

Arterial bed



Venous bed



It was found that the application of the equations of Murray C. D. for the numerical modeling of vascular dichotomies of the human kidney is limited. Using the Murray C. D. equation to calculate the value of the angle αmax is possible for any structurally different types of vascular dichotomies of the human kidney. However, the Murray C. D. equation cannot be used to calculate the values of the angle αmin for arterial and venous dichotomies of the 1st structurally different type and for the 2nd type of venous dichotomies.

Type 1 $D \neq d_{max} \neq d_{min}$ Type 2 $D \neq d_{min}$; $D = d_{max}$ Type 3 $D \neq d_{min}$; $d_{min} = d_{max}$ Type 4 $D = d_{min} = d_{max}$

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CERTIFICATE OF ATTENDANCE

This is to certify that

Ilia Miltykh

has attended

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