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DIGITAL SUBTRACTION ANGIOGRAPHY OF PERIPHERAL VASCULAR DISEASE

RAČUNALNIŠKA SUBTRAKCIJSKA ANGIOGRAFIJA PRI BOLEZNIH PERIFERNEGA OŽILJA

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Abstract — This review article discusses some of the basic principles of angiography and digital subtraction angiography (DSA) of the peripheral vascular disease. The advantages of digital subtraction angiography are described. Intra-arterial DSA can make an important contribution to the rentgenological evaluation of peripheral vascular disease.

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Review paper

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Introduction — The concept of angiography was developed soon after the discovery of X-rays when Haschek and Lindedenthal injected calcium carbonate into an artery of an amputated hand in 1896 (13). The first reported arteriograms and venograms in man were made with a 2 % solution of strontium bromide in 1923 (2). Clinically angiography became useful in the 1920's when Brooks reported the first demonstration of the vessels of the lower extremities by using intraarterial injections of sodium iodide in 1924 (4). The development of iodinated cantrast material by ment of iodinated contrast material by Swick (29) and the translumbar approach by dos Santos (10) were also important events for angiography in the late 1920's. A major advance in angiography occured in 1953 when Seldinger developed a percutaneous method of catherizing of femoral artery (25). Refinements in catheters and radiographic equipment, especially the development of image intensifier tubes, rapid film cangers and TV system, in the 1950's and 60' have brought angiography to ist current state.

Angiography of peripheral vascular disease — Peripheral vascular disease has always been one of the most common indications for angiography, and its investigation has provided much of the incentive for development of angiographic techniques. Although the diagnosis of vascular disease is now usually made by combination of clinical findings and non invasive tests, the ability of angiography to accurately define the arterial lumin and localize discrete areas of narowing remains very important. Attempts to understand the clinical significance of angiographically demonstrated lesions have led to many studies evaluating the hemodynamic effects products by various degrees of luminal narrowing (3, 17, 18, 22, 30, 36). Most of these studies have been performade in dogs by measuring the changes in blood pressure and blood flow beyond an artifically created stenosis. By comparing the cross-sectional area of the stenosis with the drop in distal blood flow a curve demonstrates that a very substantial decrease in luminal area must occur before any effect on blood flow is noted. A similar curve occurs for changes in pres-

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sure. Once this "critical" point has been reached ,there is a rapid drop in both blood flow and pressure, for even small incremental increases in stenosis. It is generally agreed that in most clinical situations, significant flow limitation will occur and a pressure gradient will develope once there has been a reduction of cross-sectional luminal area of about 70—80 %. Increased blood flow through a stenotic lesion changes the shape of the curve so that the "critical" point is reached earlier, although the hemodynamic effect are more gradual.

For many years angiography has been accepted as the standard method for detecting and determining the significance of vascular lessions. However, several studies have questioned the ability of angiography to accurately evaluate peripheral vascular disease of the lower extremities (5, 23, 28, 31, 33, 34). In a widely quoted article, Moore and Hall (23) studied 40 patients with claudication, normal femoral pulses and normal angiograms of iliac arteries. 28 of these patients were found to have significant iliac artery stenosis by hemodynamic evaluation. Of these 28,17 patients had surgical intervention, confirming the presence of significat vascular lesions in all cases. All but one of these patients treated surgically were asymptomatic or significantly improved despite the presence of distal diseasedisease Thompson et al. (33) found that arterigraphy failed to identity significant stenosis of the origin of the deep femoral artery in 75 % of 58 cases found at surgery.

Udoff et al. (34) correlated angiograms of the ilio-femoral arteries in 48 patients with hemodynamic measurements and conclude that the arteriogram is not an accurate indicator of hemodynamically significant lesions. Slot et al. (28) measured the interobserver variability in evaluating single plane angiography and found that interobserver agreement on the degree of arterial stenosis was poor, especialy involving the femoral bifurcation. They suggest that surgical decisions should not rely on angiographic information and that accuracy of non-invasive diagnostic test should not use angiography as a reference. Castenada-Zuniga et al. (5) point out that angiography tends to underestimate the significance of vascular lesins and that even severe areas of narrowing may be found at surgery that are not appreciated angiographcally.

In a review of this subject by Thiele and Strandness (31) in 1983 they stress some of the tecnical difficulties of angiographic assessmet of vascular disease, and note the unreliable results of trying to establish the functional significance of a lesion based on its angiographic appearance. As a purely morphological study they suggest that angiography is an unsuitable method for determining the clinical significance of vascular disease and should not be used in planning surgical therapy or in evaluating noninvasive technique.

One factor common to all of these studies is the use of single plane angiograms for evaluating the extent and severity of vascular disease. Despite the reference in most of these studies about the importance of biplane angiography or multiple views, their conclusions are almost entirely based on single plane AP or PA arteriograms. The principle that one projection is not adequate to accurately characterize a radiographically visualized structure or lesion dates back to the earliest days of radiology (35). Yet it is generally accepted that a single projection is adequate when evaluating peripheral vascular disease of lower extremities. any studies have examined the value of multiple and oblique projections in evaluating the vascular system and have found that arteriograms in the AP projection alone are not adequate. This is especially true in the pelvis (1, 6, 8, 14, 19, 20, 26, 27, 32, 35). Beales et al. (1) found that of 209 limbs studiede in 132 patients 38 % (81 limbs) had stenosis at the origin of the deep femoral artery. Of these 81 stenotic lesions only 30 % were visualized on the frontal view, whereas nearly 70 % required a lateral or oblique view for demonstration.

In an anatomic study Thomas and Andress (32) found that the origin of profunda femoris artery was shown optimally in the oblique projection in 75 % of patients compared with the frontal projection in which it was visualized in 35—40 %. In a small series of patients they demonstrated lesions in oblique views of the iliac and femoral bifurcations which were missed on the standard AP projections.

Similarly, a study by Sethi et al. (27) found significant lesions in 6 of 14 patients on oblique views of the femoral or iliac arteries who had either unsuspected lesions or thought to be insignificant of the AP views. Crummy et al. (8) found that multiple views provided clinically significant information in 40 % of their cases in a series of more than 500 patients. They found this technique was more accurate in evaluating the hemodynamic significance of of arterial lesions and also was valuable in detecting unsuspected lesions, both proyimally in the pelvis and distally, bellow the knee. The improved visualisation of the popliteal and trifurcation vessels afforded by multiple views significantly influenced the evaluation of distal runoff in 1/3 of their cases. This information was important in the selection of the site for distal anastomosis. In a review of 195 patienets undergoing bilateral aortofemoral bypass grafting, McDonald et al. (19) found 76 instances of stenosis of the deep femoral artery. The preoperative single view arteriograms had demonstrated only 28 of these for a false negative rate of 63 %. In a second study (20) they reviewed 116 femoral angiograms and found that the femorals arteries were adequately demonstrated in 28 of 164 AP projections (17 %), 33 of 42 ipsilateral anterior oblique projections (9 %). Significant stenosis of the deep femoral artery was demonstrated in 16 of 33 patients who had both AP and ipsilateral anterior oblique angiograms. Of these 16 stenoses was seen only on the AP projections while 13 (82 %) were seen only on the oblique projection, and 2 were seen on both projections.

There are several reasons multiple views are necessary in determining the degree of stenosis or the presence or absence of significant lesions. Moore and Hall (23) among others have pointed out that artherosclerosis tends to occur no the posterior walls of vessels — especialle in the pelvis. This may produce significant compromise of luminal area and yet not be detected angiographically on standard AP views. The anterior-posterior course of the ileofemoral arteries make the AP views poor a poor projection for outlining the arteries in this area. The posterolateral orientation of the femoral bifurcations and the posteromedial orientation of the iliac bifurcations are difficult to visualize and overlapping arteries and bones may obscure vascular lesions.

Digital subtraction angiography — The reason many studies are limited to AP views may be related to the necessity for additional contrast injections when multiple views are obtained. This not only increases the lenght of the procedure and the discomfort to the patient but it also increases the risk from contrast toxicity. A secondary consideration in increased film cost, and of these objections are solved by the use of digital subtraction angiography.

The advantages and disadvantages of digital angiography are now well recognized (7, 9, 14, 15, 16). This new imaging method has been used successfully with both IV and IA contrast injections to study peripheral vascular disease (6, 12, 15, 21, 24). Using intraarterial injections, the advantages of this technique over standard film-screen angiography are very useful in studyin vascular disease of the lover extremities. Its increased sensitivity to low levels of contrast make it possible to use diluted concentrations of contrast media, allowing visualization of poorly specified vessels. It also decreased patient discomfort and reduces risk of contrast toxicity. Overlying bone is subtracted, allowing improved visualization of arteries.

Kubal et al. (16) report a series of patients thought to have occluded runoff vessels on conventional angiography with large volume contrast injections and reactive hyperemia, but found to have patent vessels at surgery by operative angiograms. By using digital angiography they have been able to demonstrate patent runoff vessels in one third of patient vessels at surgery not demonstrated by digital studies. Instantaneus viewing of subtracted images reduces proecdure time and film costs.

The limitations of IA-DSA include a limited field of view with standard sized image intensifiers and poor spatial resolution compared to film (2 line pairs/mm vs 5 line pairs/mm), but when integrated with a single standard AP film screen angiographic run, these limitations are not important.

Conclusion — Indentification of significant vascular lesions is necessary for the effective treatment of vascular disease in the lower extremity. Accurate assessment of the vascular system in the legs and pelvis requires multiple projections for adequate visualization of the femoral and iliac bifurcations and for accurate evaluation of the significance of vascular lesions. Intra-arterial DSA can make an important contribution to the angiographic evaluation of peripheral vascular disease (fig. 1 a, b, c, d). It allows us to make multiple contrast injections without significantly increasing patient discomfort or increasing the risk from contrast toxicity. This enables us to use multiple projections to better view parts of the arterial system usually not well visualized and to more accurately evaluate arterial lesions. It also allows better visualization of faintly opacified runoff vessels beyond a high grade stenosis occlusion.

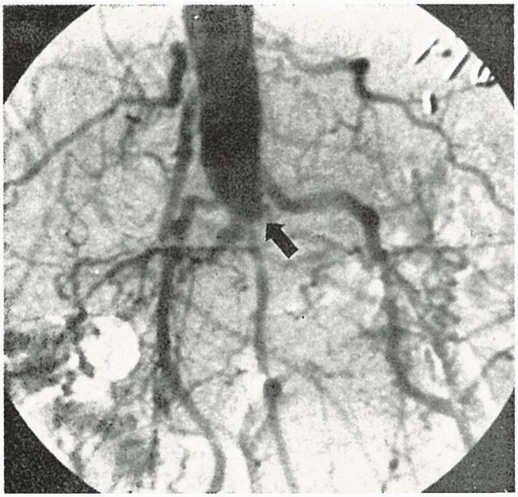

Fig. 1 a — This 66 old man had a long history of bilateral claudication. Intra-arterial DSA shows the total occlusion of the abdominal aorta at aorto-iliac level

Slika 1 a — 66-letni bolnik je imel dolgotrajno anamnezo obojestranske klaudifikacije. Intraarterijska DSA prikaže popolno zaporo trebušne aorte na prehodu le-te v mdenični arteriji

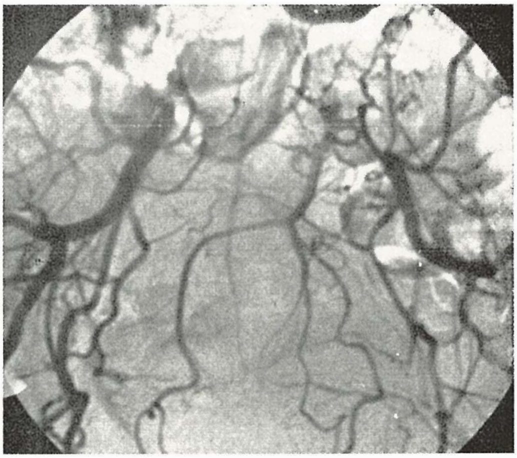

Fig. 1 b — Same patient — at the distal level (pelvis) DSA shows collateral vessels

Slika 1 b — Isti bolnik — nižje v medenici DSA prikaže kolateralno ožilje

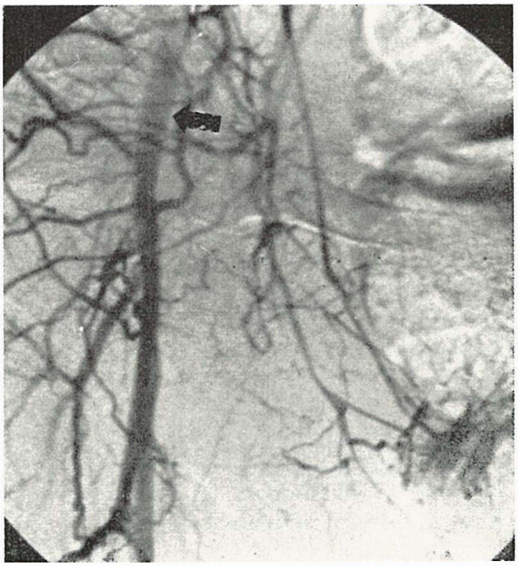

Fig. 1 c — Same patient — at the distal level, racanalisation of the right femoral artery (arrow) via collaterals is evident

Slika 1 c — Isti bolnik — nižje je jasno prikazana desna femoralna arterija (puščica), ki se polni preko kolateral

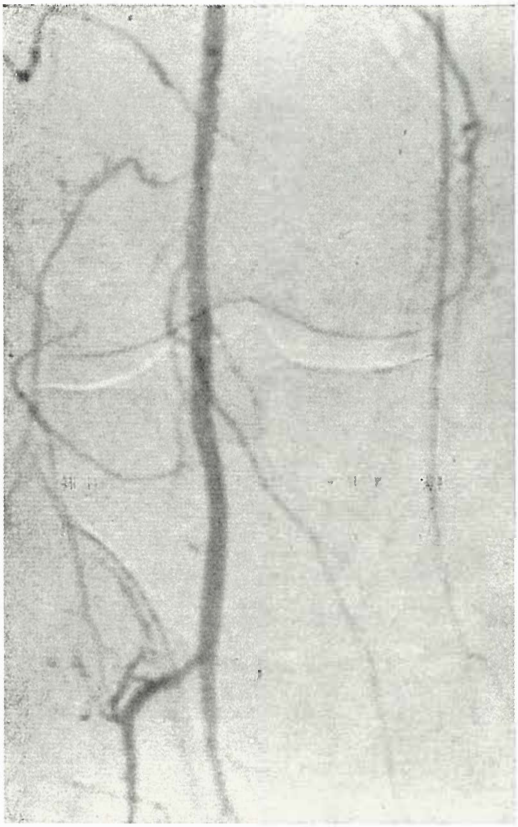

Fig. 1 d Same patient — opacification of the the right popliteal and tibial arteries is normal

Slika 1 d — Isti bolnik — slika desne poplitealne in tibialnih arterij je normalna

Currently the main limitations of Digital Subtraction Angiography are its small field of vision when usede with standard sized image intensifiers and relatively poor spatial resolution. But when used in conjunction with an initial standard filming, unr these limitations are less important.

Izvleček

Pregledni članek obravnava nekatere osnovne principe angiografije in računalniške subtrakcijske angiografije (DSA) pri boleznih perifernega ožilja. Opisane so prednosti in slabosti računalniške subtrakcijske angiografije. Intra-arterijska DSA lahko pomembno prispeva k rentgenološki oceni bolezni perifernega ožilja.

Literatura

1. Beales J. S. M., Adcock F. A., Frawley J. S., Nathan B. E., McLachalan M. S. F., Mantin P., Chir M., Steiner R. E.: The radiological assesment of disease of the profunda femoris artery. Brit. J. Radiol. 44: 854—859, 1971.

2. Berberich J., Hirsch S.: Die röntgenographische Darstellung der Arterien und Venin am Lebenden a Munchen Klin. Wochenschr. 49: 2226—2228, 1923.

3. Berguer R., Hwang N. H. C.: Critical arteriral stenosis: A theoretical and experimental selection. Ann. Surg. 180 (1): 39—40, 1974.

4. Brooks B.: Intra-arterial injection of sodium iodide. JAMA 82: 1016—1017, 1924.

5. Castaneda-Zuniga W., Knight L., Formanek A., Moore R., D'Souza V., Amplatz K.: Hemodynamic assessment of obstructive aortoiliac disease. Am. J. Roentgenol. 127: 559—561, 1976.

6. Crummy A. B., Rankin R. S., Palzkill B., Holmes K. A., Orme D. L., Gragan: Lower extremity arteriography; biplane technique. Radiology 141:33—37, 1981.

7. Crummy A. B., Stieghorst M. F., Turski P. A., Strother C. M., Lieberman R. P., Sackett J. F., Turnispeed W. D., Detmer D. E., Mistretta C. A.: Digital subtraction angiography; Current status and use of intra-arterial injection. Radiology 145: 303—307, 1982.

8. Crummy A. B., Rankin R. S., Turnispeed W. D., Berkoff H. A.: Biplane arteriography in ischemia of the lower extremity. Radiology 126: 111—115, 1978.

9. Davis P. C., Hoffman J. C.: Work in progres. Intra-arterial digital subtraction angiography: Evaluation in 150 patients. Radiology 148: 9—15, 1983.

10. Dos Santos R., Lamas A. C.. Pereira-Caldas J.: Arteriographs da Aorta E dos Vasos Abdominais. Med. Contemp. 47: 93—95, 1929.

11. Freiman D. B., Oleaga J. A., Ring E. J.: Angiography of the femoral bifurcation. Projection — of the correct oblique projection. Radiology 131: 254—257, 1976.

12. Guthaner D. F., Wexler L., Enzmann D. R., Riederer S. J., Collins W. F., Brody W. R.: Evaluation of peripheral vascular disease using digital subtraction angiography. Radiology 147: 393—398, 1983.

13. Haschek E., Linderthal O. T.: A contribution to the practical use of photography according to Röntgen. Wien. Klin. Wochenschr. 9: 63—66, 1896.

14. Kaufman S. L., Chang R., Kadir S., Mitchell S. E., White R. I.: Intraarterial digital subtraction angiography in diagnostic arteriography. Radiology 151: 323—327, 1984.

15. Kaufman S. L., Kadir R. C. S., Mitchell S. E., White R. I.: Intra-arterial digital subtraction angiography: A comparative view. Cardiovas. Intervent. Radiol. 6: 271—279, 1983.

16. Kubal W. S., Crummy A. B., Turnipseed W. D.: The utility of digital subtraction arteriogra-

phy in peripheral vascular disease. Cardiovas. Intervent. Radiol. 6: 241—249, 1983.

17. May A. G., Van Berg L., DeWeese J., Rob C.: Critical arterial stenosis. Surgery 54 (1): 250—252, 1963.

18. May A. G., DeWeese J. A., Rob C.: Hemodinamic effects of arterial stenosis. Surgery 53 (4): 513—516, 1963.

19. McDonald E. J., Malone J. M., Gooding G. W., Eisenberg R. L., Mani R. L.: Stenosis of the deep femoral artery: an evaluation of the accuracy of single-plane, anteroposterior arteriograms. Brit. J. Radiol. 19: 923—933, 1976.

20. McDonald E. J., Malone M. J., Eisenberg R. L., Mani R. L.: Arteriographic evaluation of the femoral bifurcation: Value of the ipsilateral anterior oblique projction. Am. J. Roentgenol. 127: 955—956, 1976.

21. Miller F. J., Mineau D. E., Koehler P. R., Nelson J. A., Luers P. D., Sherry R. A., Lawrence F. P., Anderson R. E., Kruger R. A.: Clinical intraarterial digital subtraction imaging. Radiology 148: 273—278, 1983.

22. Moore W. S., Sydorak G. R., Newcomb L., Campagna G.: Blood pressure gradient to estimate flow changes with progressive arterial stenosis. Surgical Forum: 248—250, 1964.

23. Moore W. S., Hall A. D.: Unrecognized Aortoiliac Stenosis: A physiologic approach to the diagnosis. Arch. Surg. 103: 55—57, 1971.

24. Rosen R. J., Roven S. J., Taylor R. F., Imparto A. M., Riles T. S.: Evaluation of aorto-iliac occlusive disease by intravenous digital subtraction angiography. adiology 148: 7—8, 1983.

25. Seldinger S. I.: Catheter replacement of needle in percutaneous arteriography: New technique. Acta Radiol. 39: 368, 1953.

26. Sethy G. K., Scott S. M., Takaro T.: The value of multiple-plane angiography in the assessment of aortoiliac disease. Southern Med. J. 70 (1): 17—19, 1977.

27. Sethy G. K., Scott S. M., Takaro T.: Multiple-plane angiography for more precise evaluation of aortoiliac disease. Surgery 78 (2): 154—159, 1975.

28. Slot H. B., Strijbosh L., Greep J. M.: Interobserver variability in single-plane aortography. Surgery 90 (3): 497—503, 1981.

29. Swick N.: Darstellung die Niere und Harnwege in Röntgenbild durch interavenose Einbring und Eines Neuen Kontrastoffers des Uroselectans. Klin. Wochenshr. 8: 2087—2088, 1929.

30. Sydorak G. R., Moore W. S.: Effect of increasing flow rates and arterial caliber on critical arterial stenosis. Surgical Forum: 243—246, 1964.

31. Thiele B. L., Strandness D. E.: Accuracy of angiographic quantification of peripheral atherosclerosis. Progress in Cardiovascular Diseases 26 (3): 4—10, 1983.

32. Thomas M. L., Andress M. R.: Value of oblique projection in translumbar aortography. Am. J. Radiol. 116 (1): 187—1983, 1972.

33. Thompson B. W., Read R. C., Slayden J. E., Boyd C. M.: The role of primary and secondary profundoplasty in the treatment of vascular insufficiency. J. Cardiovas. Surg.: 18—21, 1977.

34. Udoff E. J., Barth K. H., Harrington D. P., Kaufman S. L., White R. I.: Hemodyinamic significance of iliac artery stenosis: Pressure measurement during angiography. Radiology 132: 289—292, 1979.

35. Van Andel G. J., Krepel V. M.: Oblique projections in pelvic and femoral angiography. Medicamundi 27 (1): 19—20, 1982.

36. Van De Berg L., DeWeese J. A., Rob C. G.: The effect of arterial stenosis and sympathectomy on bloo flow and the arteriogram. Ann. Surg. 159 (4): 623—625, 1964.

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