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Intraarterial CT Angiography Using Ultra Low Volume of Iodine Contrast – Own Experiences

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: High volume of intravenous contrast in CT-angiography may result in contrast-induced nephropathy. Intraarterial ultra-low volume of contrast medium results in its satisfactory blood concentration with potentially good image quality. The first main purpose was to assess the influence of the method on function of transplanted kidney in patients with impaired graft function. The second main purpose of the study was to evaluate the usefulness of this method for detection of gastrointestinal and head-and-neck haemorrhages.

Material/Methods: Between 2010 and 2013 intraarterial CT-angiography was performed in 56 patients, including 28 with chronic kidney disease (CKD). There were three main subgroups: 18 patients after kidney transplantation, 10 patients with gastrointestinal hemorrhage, 8 patients with head-and-neck hemorrhage. Contralateral or ipsilateral inguinal arterial approach was performed. The 4-French vascular sheaths and 4F-catheters were introduced under fluoroscopy. Intraarterial CT was performed using 64-slice scanner. The scanning protocol was as follows: slice thickness 0.625 mm, pitch 1.3, gantry rotation 0.6 sec., scanning delay 1–2 sec. The extent of the study was established on the basis of scout image. In patients with CKD 6–8 mL of Iodixanol (320 mg/mL) diluted with saline to 18–24 mL was administered at a speed of 4–5 mL/s.

Results: Vasculature was properly visualized in all patients. In patients with impaired renal function creatinine/eGFR levels remained stable in all but one case. Traditional arteriography failed and CT-angiography demonstrated the site of bleeding in 3 of 10 patients with symptoms of gastrointestinal bleeding (30%). In 8 patients with head-and-neck bleeding CT-angiography did not prove beneficial when compared to traditional arteriography.

Conclusions: 1. Ultra-low contrast intraarterial CT-angiography does not deteriorate the function of transplanted kidneys in patients with impaired graft function. 2. 3D reconstructions allow for excellent visualization of vascular anatomy of renal transplants. 3. Intraarterial CT-angiography is useful for detection of the bleeding site.

MeSH Keywords: **Angiography, Digital Subtraction • Contrast Media • Gastrointestinal Hemorrhage • Infusions, Intra-Arterial • Kidney Transplantation • Multidetector Computed Tomography**

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Background

Application of a standard volume of iodine contrast in angio-CT studies requiring intravenous contrast administration may lead to worsening of renal function [1–3]. Contrast-induced acute kidney injury (CI-AKI) is defined as worsening of renal function presenting as increase in serum creatinine by 25% or 0.5 mg/dL (relative to the initial level) within 3 days from contrast administration in the absence of other factors that could potentially affect kidney function [4]. Such a condition is sometimes also called contrast induced nephropathy (CIN). Increased risk of CI-AKI is observed, i.a. among patients with initially elevated creatinine level due to chronic kidney disease, in patients after kidney transplantation suffering from graft failure, in the elderly and in diabetic patients [5]. Among patients with graft failure, if ultrasound examination fails to elucidate a vascular problem, classical catheter angiography is also associated with the necessity of administering high volume of contrast depending on the number of projections, volume of contrast per injection and concentration of contrast medium. In theory, intraarterial administration of a small amount of diluted contrast during angio-CT may be a beneficial alternative in this group of patients, although results of studies are equivocal [6,7]. If the catheter lab is located next to computed tomography facilities, as it is in case of our center, the procedure is easier to perform and the time required to complete angio-CT with intraarterial contrast application is shorter. The use of low-profile equipment by an experienced team of interventional radiologists may result in reduced frequency of complications related to intraarterial access.

Study goals were the following:

1. To establish the influence of non-selective intraarterial application of ultra-low volume iodine contrast near the orifice of renal artery on the function of transplanted kidney;
2. To assess usefulness of low-contrast angio-CT with intraarterial contrast application for assessing the anatomy of arterial tree of a kidney graft;
3. To assess the usefulness of angio-CT with intraarterial contrast application for diagnosis of extravasations in clinically symptomatic episodes of gastrointestinal bleeding with negative mesentericographies;
4. To assess the usefulness of angio-CT for precise localization of a bleeding vessel in the craniofacial region as well as detecting abnormal connections with internal carotid artery, which might potentially translate into therapeutic decisions regarding the embolization strategy;
5. To assess complications following low-profile intraarterial access;

Material and Methods

Study group

In the years 2010–2013 angio-CT with intraarterial administration of contrast was performed due to a variety of clinical indications in a total of 56 patients. Informed consent to angio-CT with intraarterial contrast was obtained from all patients. Patients with renal disease comprised the largest group of 28 patients, including 18 patients (5 women, 13 men; mean age 45 years) after renal transplantation with graft dysfunction and/or clinically significant arterial hypertension. Patients with renal disease were characterized by increased renal artery blood flow velocity Vmax. of over 150–200 cm/s, raising a suspicion of renal artery stricture due to anatomical reasons, most common of which were elongation and tortuous course of the vessel. Another study group included 10 patients with clinical symptoms of gastrointestinal bleeding, in whom endoscopic studies failed to confirm upper or lower gastrointestinal tract bleeding. These patients were referred for visceral vessel arteriography. Initial arteriography of the celiac trunk and mesenteric arteries did not visualize the site of active bleeding. Ultimately, that group of patients underwent angio-CT study with intraarterial contrast administration. The third group (n=8) consisted of patients with bleeding in the craniofacial area, who were subjected to classic arteriography and simultaneous angio-CT with contrast administered via external carotid artery. Remaining patients were not included in the analysis due to low representativeness of particular subgroups. All patients underwent serum creatinine measurements prior to arteriography, which was subsequently monitored for another 3–4 days.

Methodology

In all patients femoral artery puncture was performed with Seldinger method using a one-piece needle. A 4F hemostatic sheath (Cordis, Boston Scientific) with a distal marker was introduced, while 4F pigtail catheters (Cordis, Boston Scientific) were used in the diagnostic phase. In patients after renal transplantation we used ipsilateral inguinal access, placing the catheter about 2 cm below aortic bifurcation. Contralateral approach with similar positioning of the pigtail catheter tip was used in 3 cases only. In cases involving diagnostics of craniofacial bleeding, the catheter tip was placed selectively in the ostium of the external carotid artery under fluoroscopic guidance and using the roadmapping technique. In cases involving gastrointestinal bleeding, the catheter tip was placed selectively in the ostium of the superior mesenteric artery or in the aorta under fluoroscopic guidance. Cobra 2 4F (Boston Scientific), Simmons 1 (Boston Scientific) or 4F pigtail (Cordis, Boston Scientific) catheters were used for superior mesenteric artery catheterization. Catheter tips were placed at the level of Th10–Th11 vertebrae in order to obtain optimal mixing of contrast with inflowing blood. Head Hunter 1 4F or Simmons 2 4F catheters were used for external carotid artery catheterization. Renal artery diagnostic catheter was positioned under fluoroscopic guidance without contrast, identifying the precise location of aortic bifurcation based on observable pigtail catheter activity. At the end of the examination, pressure dressing was applied in patients in whom low-profile equipment or 4F hemostatic sheaths were used. If there were indications for an intervention, a 4F sheath was replaced with 5F or 6F sheaths. In cases where equipment of a larger diameter was used, either pressure dressing, Star Close (Abbott) system or Angio Seal (St. Jude) system was applied depending on clinical and anatomical conditions. Imaging studies were performed using 64-slice LightSpeed CT (GE Healthcare). The following examination protocol was used: collimation 0.625 mm, pitch 1.3, gantry rotation time 0.4 sec., scanning delay 1–2 sec. The extent of examination was established individually based on an overview scan – for renal transplant examination ranging from about 3 cm above the upper renal pole to the level of the greater trochanter of the femoral bone. Scanning direction was concordant with the direction of blood flow. A high-pressure MARK V (Medrad) syringe with two cylinders was used for injections. About 6–8 mL of contrast (Iodixanol 320) was diluted using saline

Table 1. Creatinine levels measured prior to and 4 times following intraarterial CT-angiography of renal transplants.

No.	Baseline creatinin level	Measurement 1	Measurement 2	Measurement 3	Measurement 4
1.	1.31	1.32	1.3	1.34	1.33
2.	2.68	2.7	2.7	2.69	2.67
3.	2.4	2.25	2.28	2.56	2.5
4.	1.84	1.86	1.82	1.99	1.91
5.	2.75	2.48	2.7	2.9	3.1
6.	4.97	7.7	9.04	7.6	10.4
7.	2.3	1.88	1.88	1.72	1.45
8.	1.56	1.55	1.34	1.6	1.58
9.	2.62	2.2	1.92	1.85	1.98
10.	5.38	6.52	5.02	7.7	5.28
11.	1.8	1.78	1.85	1.89	1.75
12.	8.73	6.13	8.18	8.47	6.43
13.	1.55	1.66	1.88	1.98	2.05
14.	6.91	4.9	5.9	4.89	5.59
15.	1.55	1.86	1.57	1.78	1.98
16.	3.14	3.06	2.52	3.54	3.53
17.	3.46	3.25	2.84	2.44	2.53
18.	4.41	4.44	4.59	6.33	5.48
Mean	**3.30**	**3.19**	**3.29**	**3.54**	**3.42**

to 18–24 mL in order to obtain 30% concentration and subsequently administered through the catheter at a speed of 4–5 mL/sec. into the internal iliac artery on the side ipsilateral to the transplanted graft. About 4 mL of contrast medium diluted with saline to 12 mL was administered to the superior mesenteric artery and external carotid artery at a speed of 2–3 mL/sec. Scanning delay equaled 3 seconds. About 8–12 mL of contrast diluted with 20 mL of saline was administered into the aorta at a speed of 6–8 mL/sec. Scanning delay equaled 3 seconds.

Obtained images were analyzed using AW 4.4 (GE Healthcare) diagnostic station manually or with Vessel Analysis software. 3D MIP (Maximum Intensity Projection) and CPR (Curved Planar Reconstruction) reconstructions were made in order to assess the extent of stenosis and length of the narrowed portion of a vessel. VR (Volume Rendering) reconstructions were also additionally performed.

Results

Diagnostic images were acquired in all 18 renal transplant patients, which were subsequently analyzed using a diagnostic station allowing for 3D reconstruction and automatic

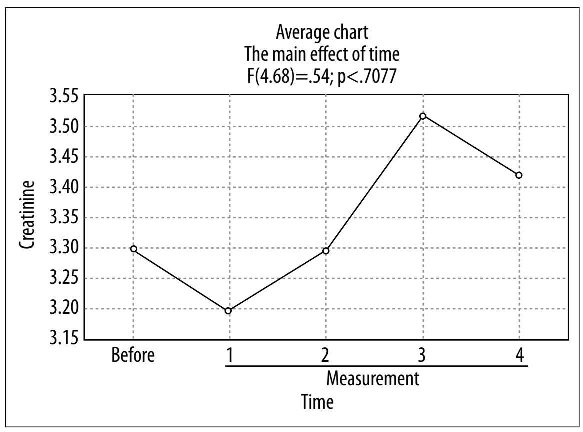

Figure 1. Diagram presenting fluctuations of creatinine levels over time – no statistically significant changes [p<0.7; ANOVA test].

measurements. Hemodynamically significant strictures were found and subsequently treated with stent implantation in 10 of 18 patients after renal transplantation (56%). Good anatomical outcome and improvement in renal function was seen in all cases. The remaining patients were treated pharmacologically. During follow-up creatinine

Table 2. Patients with gastrointestinal bleeding.

No.	Initial	Sex	Age	Location of catheter tip	Symptoms of extravasation in classic arteriography	Symptoms of extravasation in angio-CT	Site of embolization	Complications
1.	ZW	M	57	AMS	+/–	+	AMS	+
2.	ZW	M	57	AMS	+/–	+	AMS	–
3.	KZ	M	26	AO	–	–	–	–
4.	WK	M	92	AMS	+/–	+	AMS	–
5.	BS	M	45	AO	–	–	–	–
6.	ZL	M	60	AO	–	+	AGD	–
7.	IZ	M	67	AMS	–	+	AMS	–
8.	CL	M	61	AO	–	+	AMS	+
9.	R L-W	M	78	AO	–	–	AGD	–
10.	BB	M	33	AMS	+/–	+	AMS	–
11.	EW	F	68	AO	+/–	+/–	AGD	–

AMS – superior mesenteric artery; AGD – gastroduodenal artery; AO – aorta.

measurements performed for 3 days following contrast administration, we observed only one statistically significant elevation of this parameter (Table 1: patient no. 6). The statistical analysis of creatinine measurements before and after the test, as well as analysis of changes in this parameter in time did not reveal statistically significant differences for the entire group (ANOVA with repetition, Figure 1).

Arteriography and angio-CT with intraarterial contrast administration was performed in 10 patients (9 men/1 woman) with clinical symptoms of gastrointestinal bleeding; one patient underwent the procedure twice (Table 2). The catheter tip was placed in the orifice of the superior mesenteric artery (n=5) or in the aorta (n=6). In 3 cases classical arteriography did not reveal the site of bleeding, while it was revealed in angio-CT. In 5 cases arteriographic image raised doubt as to precise location of bleeding. In this subgroup, source of bleeding was identified with angio-CT in 4 patients and in 1 case the result was equivocal. In another 2 cases classic arteriography and angio-CT were negative despite the provocation test with papaverine. In one of those patients embolization was not performed. Another patient, who had been previously diagnosed with duodenal ulcers, underwent empirical embolization of the gastroduodenal artery. In 2 patients we observed complications related to embolization, presenting as recurrent gastrointestinal bleeding. In the first patient bleeding recurrence occurred after 24 hours and was confirmed by angio-CT and subsequently by arteriography performed during a procedure. On the following day the patient presented with clinical picture of intestinal obstruction and was referred for open surgery. However, no signs of necrosis of the embolized small intestine were noted during the operation. In the second patient bleeding recurred after 14 days; performed angio-CT with intraarterial contrast did not reveal the source of bleeding. Patient was closely monitored and treated conservatively.

In the third group consisting of 8 patients with craniofacial bleeding we did not demonstrate the advantage of angio-CT with intraarterial contrast relative to classic arteriography, neither with regard to determination of the bleeding site or assessment of internal and external carotid artery anastomoses. Therefore, that diagnostic method was renounced.

In the analyzed group of 56 patients the diagnostic procedure was conducted using a low-profile equipment (4F sheaths and catheters). We did not observe any complications related to arterial puncture or catheter insertion.

Discussion

Direct intraarterial administration of contrast in angio-CT has many benefits and one disadvantage. The first benefit is related to acquiring high concentration of contrast in the vessel of the interest with a small overall volume of the administered contrast medium. Using small volumes of iodine contrast is of particular significance in patients with renal impairment [8]. It may be also applied in patients with high blood creatinine levels with contraindications (according to some recommendations) to conventional contrast CT examination [9]. High concentration of contrast combined with isotropic imaging and ability of computed tomography to produce reconstructions should carry greater diagnostic value compared with classic catheter angiography. Another possible advantage of this technique is the potential for localizing blood extravasation, since classic arteriography allows for diagnosing bleedings at a rate of about 0.5 mL/min. Disadvantages include the need for arterial puncture and introduction of diagnostic catheter in the examined area. However, such an inconvenience is only associated with assessment of renal vessels, while patients with bleeding were transferred to the CT examination room following a negative result of classic arteriography. Transporting a patient from a cathlab into the CT room

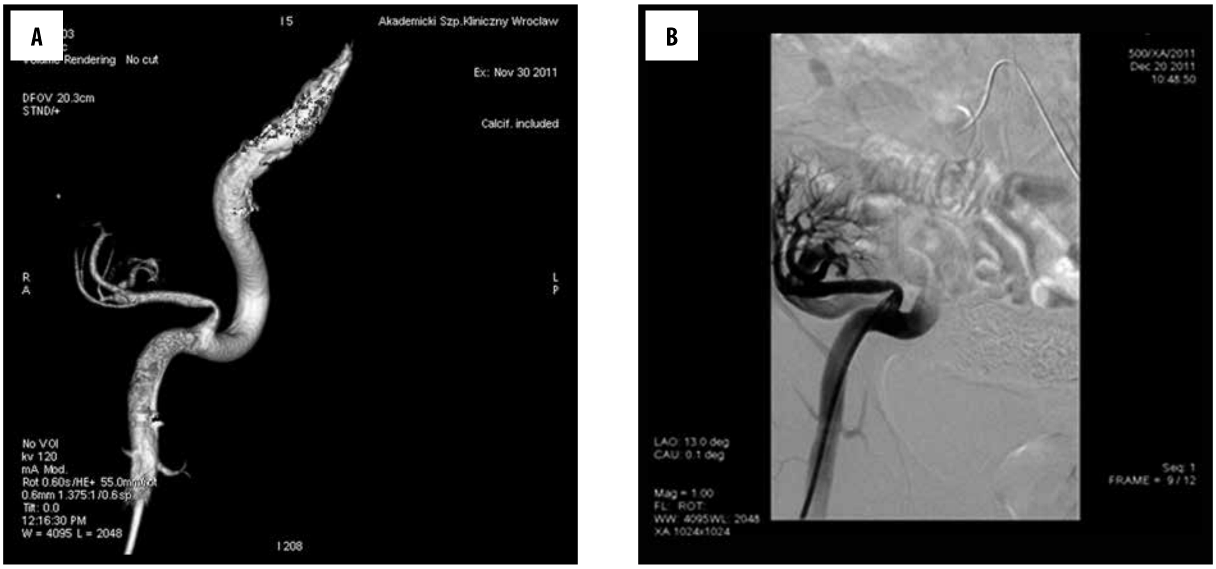

Figure 2. (**A**) Ultra-low intraarterial contrast angio-CT (volume of contrast – 6 mL). (**B**) DSA in the same patient performed directly prior to stenting of the renal artery in the transplanted kidney.

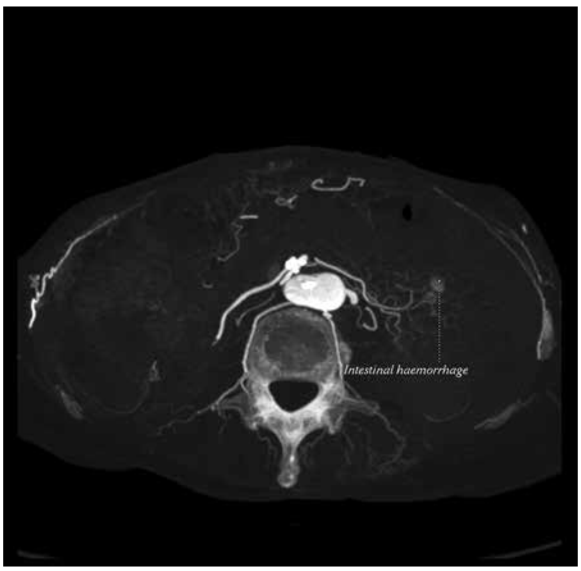

Figure 3. Axial angio-CT image (after administration of 8 mL of iodine contrast) demonstrating contrast extravasation.

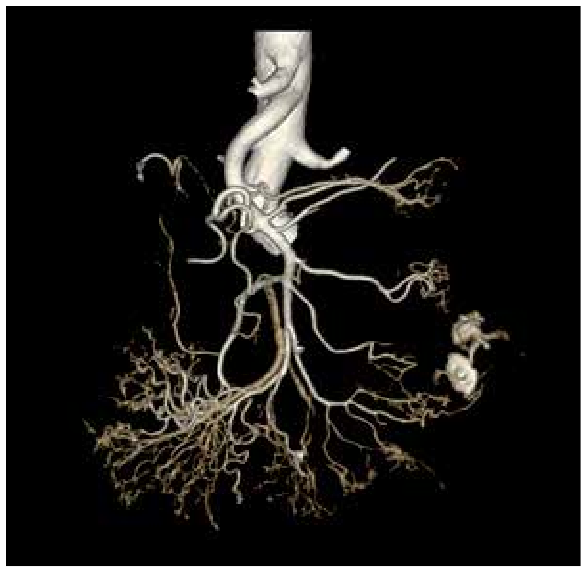

Figure 4. Volume rendering (VR) reconstruction of angio-CT scan clearly demonstrating contrast extravasation.

may be a logistic challenge. It should be emphasized that experience of the technician and the doctor supervising the study exert significant influence on the quality of imaging. Intraarterial contrast administration in angio-CT was first used for the diagnosis of peripheral arterial diseases in the lower limbs conducted simultaneously with cardiological procedures [10].

The study included 18 patients after renal transplantation with graft dysfunction presenting as elevated creatinine level and/or arterial hypertension. The first-line imaging study in this clinical group is still Doppler ultrasound, although it is relatively frequently nondiagnostic or yields equivocal results, particularly among patients with obesity or in the early postoperative period. Elongation of the graft artery, its tortuous course or kinking frequently causes problems in diagnostic imaging. Maximal velocity increase of over 2 m/sec is not entirely reliable for the diagnosis of significant renal artery stenosis [11]. Precise classic arteriographic examination of the transplanted kidney requires administration of several doses of concentrated contrast into the iliac artery or directly into the renal artery. Application of angio-CT with intraarterial contrast administration in the diagnostic part of the procedure allows for significant reduction of the total volume of contrast if there is a need for stent implantation (Figure 2). Excellent visualization of vascular anatomy obtained in all patients, as well as identification of strictures, facilitated proper therapeutic decision-making process with regard to safe and effective renal artery stenting, renouncing this therapeutic method, shortening the time of the procedure, choosing appropriate projection for intervention and, as a result, increased procedure safety. Effectiveness of this method was presented during 2013 ECR [12] and subsequently in a 2014 publication based on a group of 11 patients [13].

The second group of patients consisted of patients with gastrointestinal bleeding with negative arteriography of visceral vessels. Arteriography of bleeding from the small intestine is problematic, as typically increased peristalsis and presence of intestinal gas make it difficult to detect the site of bleeding due to formation of artifacts during DSA [14]. In such cases we take into consideration indirect signs, even after provocation tests. Embolization is risky for a patient under such circumstances. Due to the presence of arterial arcades closing the last distal vessel is a rule. Following indirect signs leads to unintentional embolization or extended embolization, which is related to possible complications, such as necrosis of the intestinal wall. On the other hand, if the procedure is not performed, relapse is frequent and often life-threatening. Application of angio-CT with intraarterial contrast administration enabled precise localization of bleeding source in 6 out of 10 patients, facilitated guidance into the site of interest and allowed for performing safe and effective embolization (Figures 3, 4). We did not find in the available literature any reports of using such a diagnostic method for the gastrointestinal tract. We believe that this method requires further investigation, including use of provocation tests in angio-CT following negative classical arteriography.

In a group of patients with craniofacial bleeding the goal of the study was to identify the site of bleeding and to assess vascular anatomy using 3D reconstruction in order to establish the best access to the target vessel. Another important matter involved assessment of anastomoses between the external carotid artery (ACE) and internal carotid artery (ACI). Visualization of those vessels is of great importance in terms of safety of embolization since embolization material may be displaced into the CNS under changed hemodynamic conditions during the procedure, causing complications in 25–58% of cases, including serious complications such as stroke or blindness in 1% of cases [15]. However, the analysis did not demonstrate the advantage of this study over classic angiography with regard to the detection of such anastomoses. In this group of patients better results of imaging connections between ACE and ACI ensued from the possibility of applying rotational angiography and 3D reconstruction. Artifacts in angio-CT hindered precise determination of blood extravasation site. Therefore, we renounced further attempts at diagnosing craniofacial bleeding using the low-contrast method.

Analysis of complications among patients in whom we used low-profile equipment did not identify any complications related to vascular access despite the fact that elderly patients and patients with advanced atherosclerosis comprised a large proportion of study subjects.

Conclusions

1. Angio-CT with intraarterial application of ultra-low volume of contrast does not cause worsening of renal function and may be used safely for diagnostic imaging of renal vessels after kidney transplantation.
2. Angio-CT 3D reconstruction after intraarterial contrast administration provides excellent visualization of the anatomy of the transplanted kidney.
3. Angio-CT with intraarterial administration of contrast may be useful for detection of gastrointestinal bleeding, although further investigation is necessary.
4. There is no advantage of ultra-low contrast intraarterial angio-CT over classic arteriography in the diagnostics of craniofacial bleeding.
5. Angio-CT with intraarterial administration of contrast medium using low-profile equipment does not lead to complications at the site of vascular access.

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