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This information is current as of June 23, 2025.

AJNR Am J Neuroradiol 1984, 5 (4) 361-366
http://www.ajnr.org/content/5/4/361

Examination of the Extracranial Carotid Bifurcation by Thin-Section Dynamic CT: Direct Visualization of Intimal Atheroma in Man (Part 2)

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Examination of the extracranial carotid bifurcation by thin-section computed tomographic (CT) scans after bolus, high-volume contrast enhancement allowed detection of more disease than did arteriograms in six of eight consecutive patients with transient ischemic attacks. In four patients this was on the clinical side of the lesion; in two the disease was in the asymptomatic carotid artery. One patient appeared to show a carotid ulcer; the ulcer was detected on CT. However, at surgery and subsequent histology, the surface of the lesion was endothelialized. The carotid CT examination is performed in the scanner "dead time" between unenhanced and enhanced head CT scans using the same contrast material for both studies. The examinations covers 3–3.6 cm of the carotid bifurcation region. Thin-section CT of the extracranial carotid arteries is a noninvasive examination that on preliminary evaluations appears to have sensitivity at least equal to that of carotid angiography in the detection of intimal disease.

Thin-section bolus contrast computed tomography (CT) has been investigated as a means to improve visualization of arterial intimal disease—plaques and thrombi—in patients who have transient ischemic attacks (TIAs) and amaurosis fugax. Preliminary work with carotid specimens indicates that multiple cross-section slices of the carotid arteries at frequent intervals can reveal thrombi and atheroma within the lumen [1]. This may represent a substantial additional capability to present noninvasive carotid artery diagnostic studies, such as oculoplethysmography and B-mode sonography with Doppler analysis. If the detection sensitivity were good, a CT neck study done at the time of initial head scanning could provide indications for subsequent angiography. We report eight consecutive TIA patients in whom both CT and angiography were undertaken so that the two methods could be compared.

Received August 3, 1983; accepted after revision February 17, 1984.

This work was supported by National Institutes of Health grant 1 R01 NS/HL 16759-01.

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AJNR 5:361–366, July/August 1984
0195–6108/84/0504–0361 $2.00
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Subjects and Methods

Eight consecutive male patients 42–64 years old with amaurosis fugax or TIAs had both CT studies of the neck and angiography. All had sustained more than one ischemic event. Most of the patients underwent catheter angiography with two or more views of the carotid artery on the affected side. Case 3 had left and right posterior oblique arch angiograms. Case 6 had an intraarterial digital angiogram of good quality. As CT shows both carotid arteries, we were able to make comparisons in 15 of 16 arteries. Our CT technique was described in part 1 [1].

A grading system was used in the evaluation of atheroma within the carotid artery. The system is based on the area of the lumen involved: 1%–10% is 1+; 11%–25% is 2+; 26%–50% is 3+; and 51%–90% is 4+. Endarterectomy specimens were obtained in two of the three patients who had carotid surgery.

TABLE 1: **Cervical CT versus Angiography in the Detection of Carotid Intimal Disease**

Clinical Condition: Case No. (side)	R Carotid		L Carotid		Comments
	CT	Angiography	CT	Angiography	
Amaurosis fugax:					
1 (L)	Bifurc lateral wall: 1+; RIC medial wall: 1+	Normal	CC lateral wall: 1+; bifurc: post wall dissection; LIC: 3+ atheroma	Bifurc 1+; LIC 1+	Atheroma lat wall CC; dissection at bifurc L; and LIC atheroma not detected by angio; RCC and RIC antheroma not shown by angio
4 (R)	RIC: 1+	Normal	CC: 2+; bifurc: 2+; LIC: normal	Normal	CT detects 1+–2+ atheromas; digital subtraction misses
5 (R)	CC: 1+ post wall atheroma	Normal (not selective)	Normal	Normal	CT detects atheroma; angio does not
Carotid TIAs:					
2 (R)	CC: 3+ medial wall; bifurc: 2+ medial wall; RIC: 2+ ant wall	CC: 2+; bifurc: 1+; irregularity ant wall; normal RIC	CC: 1+; bifurc: post wall 2+; LIC: 1+	Post wall: 1+	CT CC shows 40% (3+) narrowing RC; angio 2+ bifurc; medial wall atheroma not shown on angio; RIC: CT showed 2+ atheroma; angio, neg
6 (L)	CC: 2+; bifurc: 2+; RIC: 4+	40% narrowing large excavation; RIC narrowing not seen	CC: 4+ atheroma, almost complete occlusion; extends from below bifurc to prox LIC	98% occlusion	RIC: 4+; narrowing not appreciated on angio
7 (L)	RIC: 2+	Normal	LIC: 1+ post wall	LIC: post wall 1+ plaque	CT detects CC post wall atheroma and internal carotid atheroma missed by angio (R)
3 (L)	Normal	Normal	2+ post wall atheroma	Bifurc: subtle post wall plaque	CT atheroma is much larger than angio lesion
8 (R)	Normal	Normal	Normal	Normal	. . .

Note.—R = right; L = left; TIAs = transient ischemic attacks; bifurc = bifurcation; RIC = right internal carotid; CC = common carotid; post = posterior; LIC = left internal carotid; angio = angiography; ant = anterior; prox = proximal; 1+ = 1%–10% narrowing; 2+ = 11%–25% narrowing; 3+ = 26% –50% narrowing; 4+ = 51%–90% narrowing.

Results

Our observations are presented in table 1. Note that calcification is seen frequently in these studies, but it was always located in the wall and not in the intimal atheroma. Therefore, calcification, which was suggested as a sign of carotid atherosclerosis [2], was an *indirect* expression of the state of the intima.

Correlation of CT and angiographic findings shows that six of eight patients had additional or more severe pathology disclosed by CT than by angiography (cases 1–6). In cases 1–5 (figs. 1–4), the pathology was noted on the side of the clinical lesion; in cases 4 and 7 (fig. 4), the pathology was noted in the opposite asymptomatic carotid artery. In the one case examined by the GE 9800, the detail of the carotid artery and atheroma (fig. 4) was much better than on the other images, all of which were taken from the GE 8800. As the GE 9800 permits 3 mm scans with table increments of 3 mm, the scanning time falls to about 5 min with a commensurate decrease in contrast material requirements to about 50 g of iodine.

Specimens were obtained at surgery in cases 1 and 2. While the angiogram in case 2 appeared to show an ulcer on the posterior wall, the specimen did not confirm it (fig. 1). The atheromatous plaque had endothelium covering it.

Discussion

The CT studies are not able to differentiate atheroma from thrombus at this time. We know that CT can detect each, as we have demonstrated thrombus in the postmortem phantom studies and atheroma in the surgical studies, but have not seen differentiating characteristics. It is possible that recent clot may show higher CT numbers when compared with atheroma, but this remains to be investigated.

Some objections may be raised to this report because of the limited scope of the neck study, in which only 3–3.6 cm

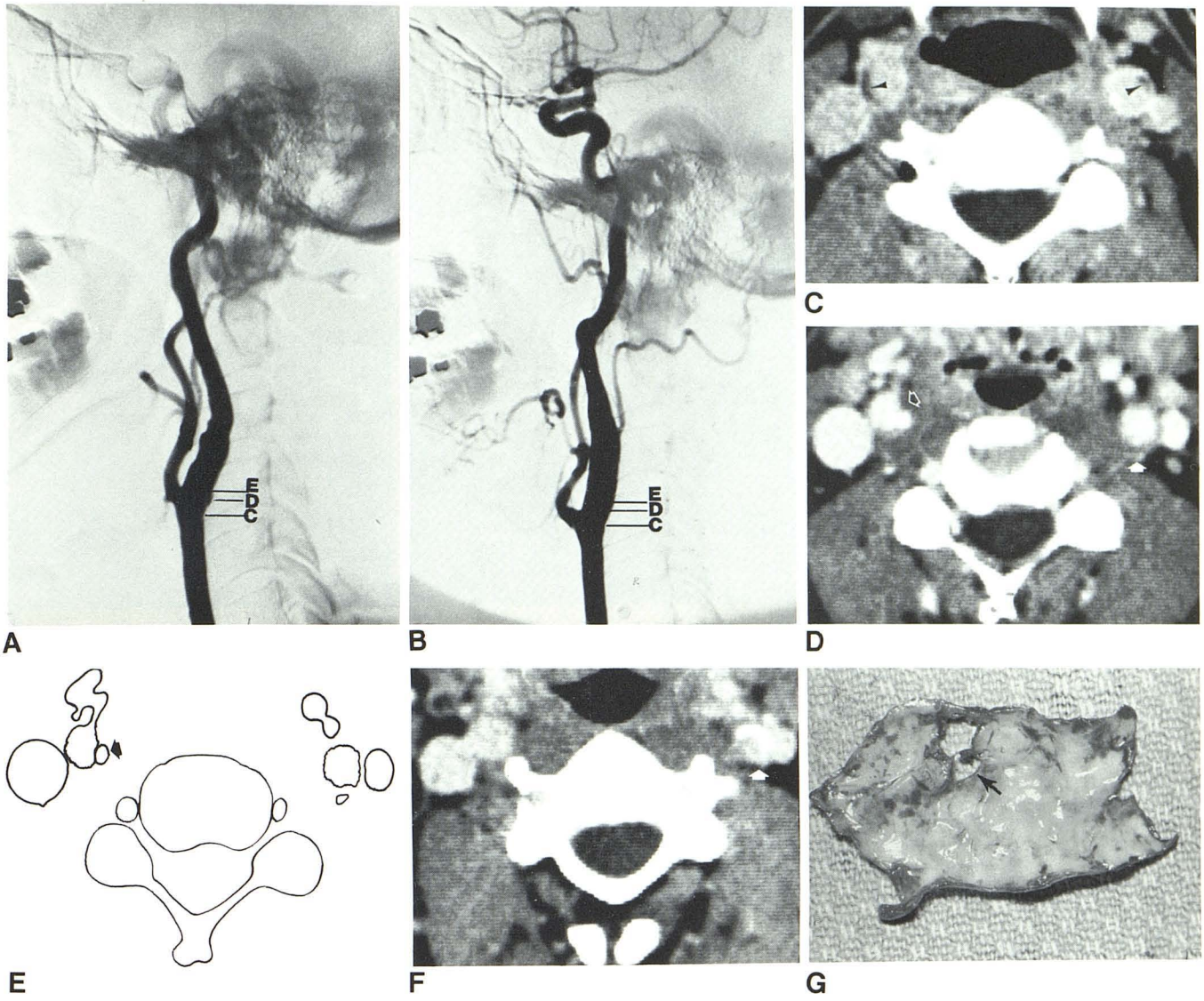

Fig. 1.—Case 1, 60-year-old man with repeated episodes of left amaurosis fugax. **A,** Left carotid angiogram shows minimal irregularity in left common carotid artery. CT (**C, D,** and **F**) shows 1+ changes on lateral wall (C). Just above bifurcation (D), there is 1+ change on angiogram, and CT shows comparable posterior wall change of dissection (*closed arrows*, **D** and **F**). Proximal left internal carotid artery angiogram shows posterior wall changes of 1+, which are confirmed by extraluminal dissection on CT. **G,** Specimen from left carotid showing area of dissection (*arrow*). **B,** Right carotid angiogram. Right (asymptomatic) carotid artery does not appear narrowed but has unusual shape. There is 1+ change in lateral wall at bifurcation (*arrowheads*, **C**) and 1+ change in medial wall of internal carotid artery (*open arrow*) not seen on angiogram. **E,** Line drawing illustrates posterior wall left carotid dissection and calcification (*arrow*) of medial wall of right carotid (D).

of carotid artery was examined. However, this is the same territory covered by B-mode and Doppler sonography, and, further, it covers the primary location of significant carotid artery atheromatous disease as described in postmortem angiographic studies. It also corresponds to the area where essentially all of the carotid artery surgery takes place: the carotid bifurcation and proximal internal carotid artery. Therefore, any noninvasive study that can adequately encompass

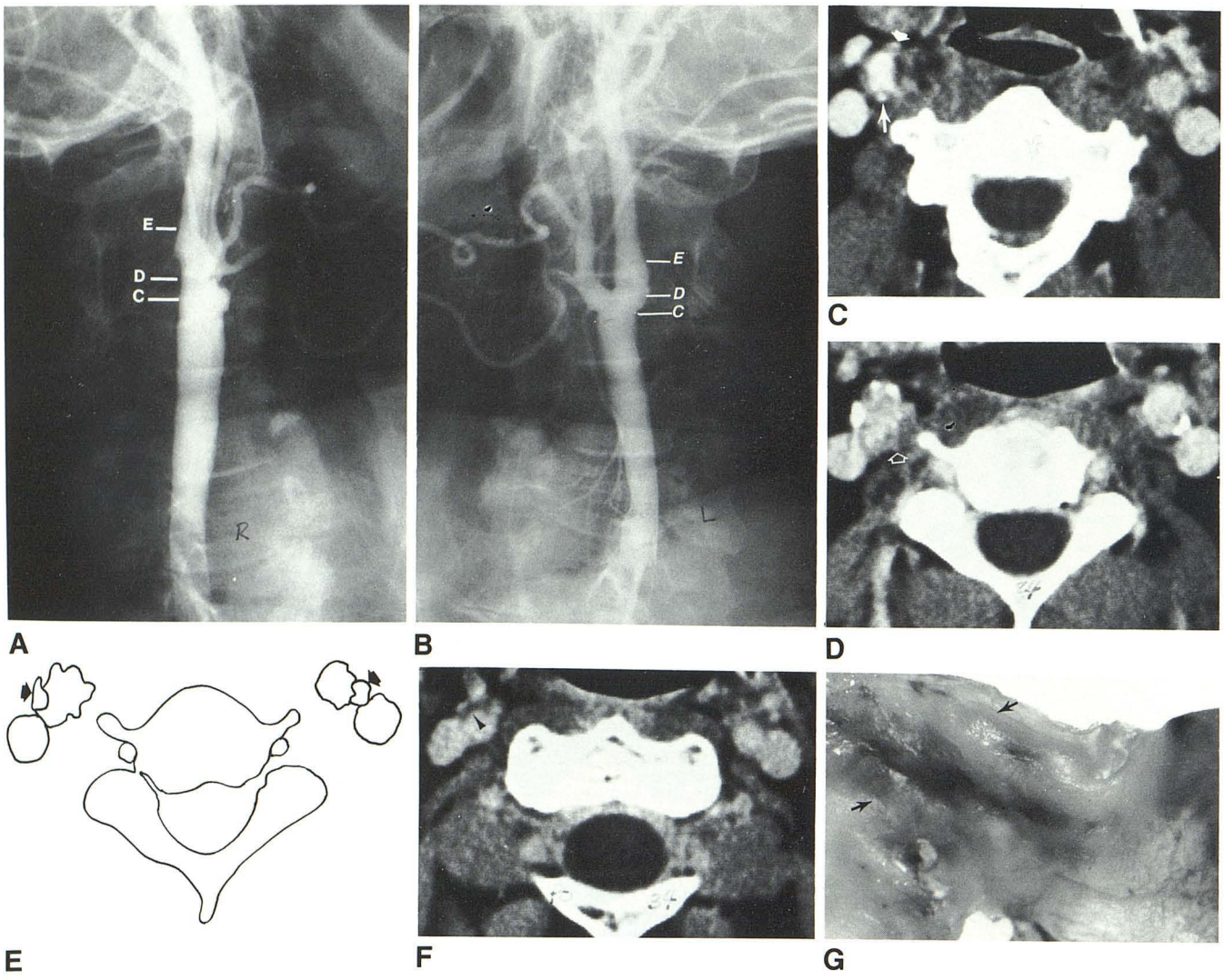

Fig. 2.—Case 2, 46-year-old man with right carotid TIAs. **A,** Right carotid angiogram shows 2+ anteromedial atheroma with excavation. CT (**C, D,** and **F**) shows 2+ change in right common carotid with anteromedial atheroma and excavation (*short arrow*, **C**). Posterior wall irregularity not seen on angiogram (*long arrow*, **C**). Anterior wall atheroma in internal carotid artery (*arrowhead*, **F**). **E** is a line drawing of **D.** *Arrows* point to large calcifications in right and left carotid walls seen in **D. B,** Left carotid angiogram shows no change in common carotid; CT shows 2+ atheroma (*arrows*, **D**). **G,** Surgical specimen from right carotid. There was healed excavation in atheromatous plaque (*arrows*).

the carotid bifurcation will fulfill much of the clinical need for a screening procedure.

Digital angiography is a significant advance in the search for a less invasive diagnostic examination of the carotid artery. However, despite early enthusiasm for the digital venous studies, many centers are moving to intraarterial digital examinations. In many instances (as in our case 4) an intracarotid artery injection was made. These intraarterial selective injections are undertaken to provide the best possible resolution of the intimal disease while still using digital techniques. Therefore, arterial catheterizations, including selective carotid catheterizations, are still performed frequently. Apart from

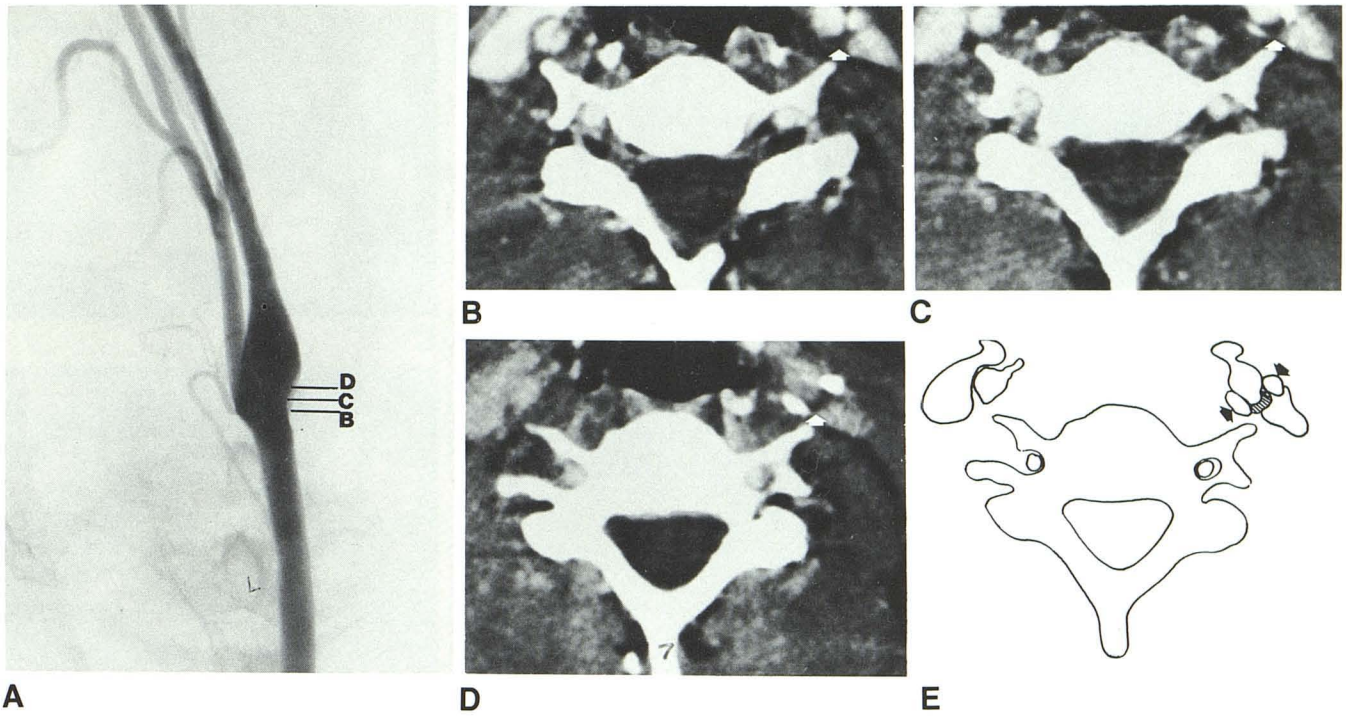

Fig. 3.—Case 3, 45-year-old man with left brain TIAs. **A,** Angiogram. Intimal defect (1+) on posterior wall of internal carotid artery at bifurcation. CT (**B–D**) shows 2+ change (CT plaque appears larger than on angiogram) on posterior wall of internal carotid at bifurcation (*arrows*). Two calcium deposits lie within wall of artery and not in atheroma (**C** and **D**). Atheroma demonstrated on CT is much larger than that seen on posterior wall on lateral angiogram, in which central ray is tangent to lesion. **E** shows posterior wall atheroma (*shaded area*). Two carotid wall calcium deposits (*arrows*).

shortening the catheterization time and decreasing the amount of contrast material, digital angiography has resulted in little real reduction in invasiveness.

In contrast, it is apparent from our study that detection of atheromata in the carotid bifurcation can be achieved by a much less invasive study. Further, CT examination of the neck provides sufficient contrast material for the head study that follows it. Thus, CT examination of the carotid arteries in the neck as part of an initial enhanced CT study of the head appears to be a minimally invasive, potentially sensitive method for the detection of disease in the carotid artery.

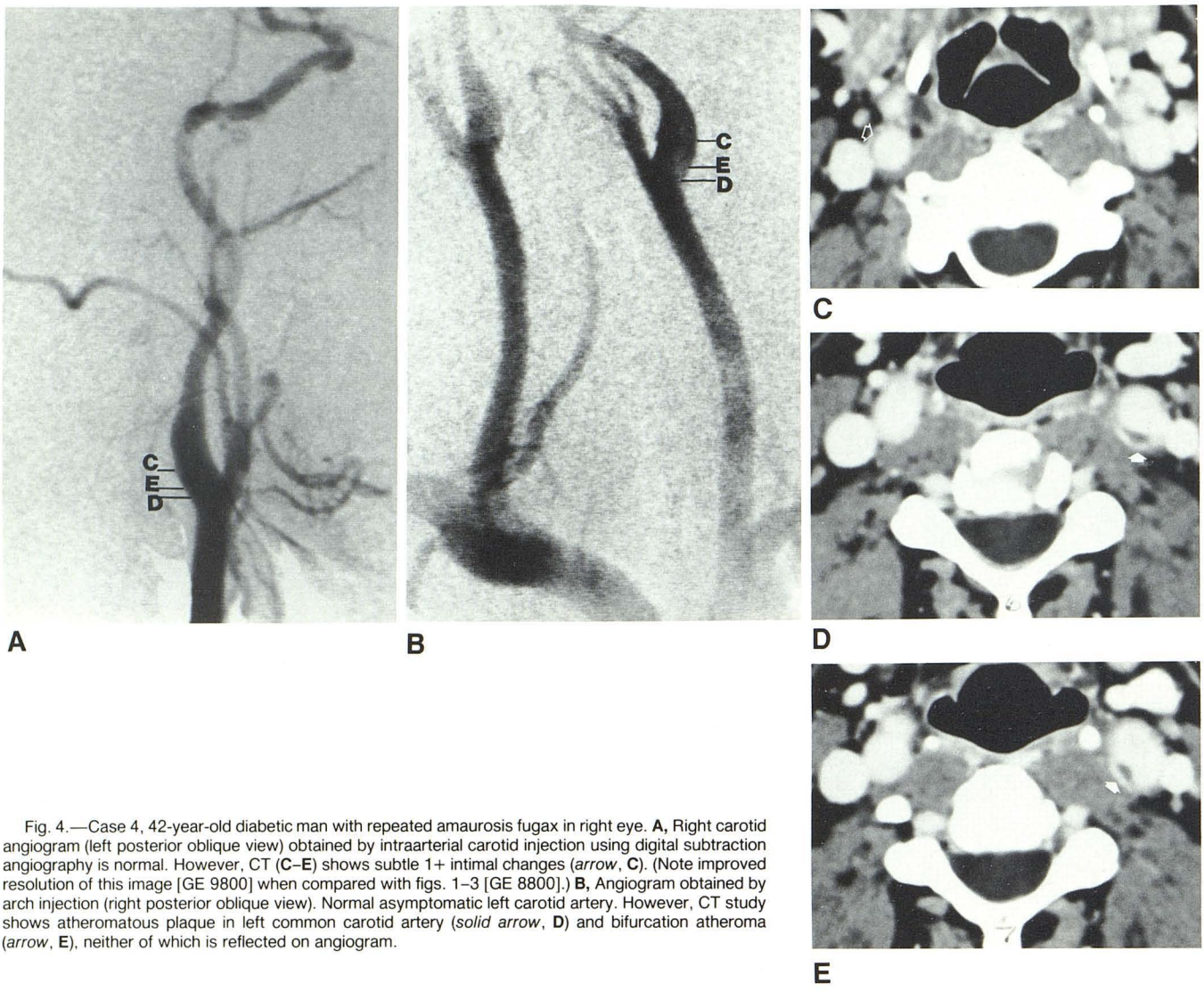

Fig. 4.—Case 4, 42-year-old diabetic man with repeated amaurosis fugax in right eye. **A,** Right carotid angiogram (left posterior oblique view) obtained by intraarterial carotid injection using digital subtraction angiography is normal. However, CT (**C–E**) shows subtle 1+ intimal changes (*arrow*, **C**). (Note improved resolution of this image [GE 9800] when compared with figs. 1–3 [GE 8800].) **B,** Angiogram obtained by arch injection (right posterior oblique view). Normal asymptomatic left carotid artery. However, CT study shows atheromatous plaque in left common carotid artery (*solid arrow*, **D**) and bifurcation atheroma (*arrow*, **E**), neither of which is reflected on angiogram.

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