Common iliac artery aneurysm: Expansion rate and results of open surgical and endovascular repair

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Objectives: **To assess expansion rate of common iliac artery aneurysms (CIAAs) and define outcomes after open repair (OR) and endovascular repair (EVAR).**

Methods: **Clinical data of 438 patients with 715 CIAAs treated between 1986 and 2005 were retrospectively reviewed. Size, presentations, treatments, and outcomes were recorded. Kaplan-Meier method with log-rank tests and χ^2 test were used for analysis.**

Results: **Interventions for 715 CIAAs (median, 4 cm; range, 2-13 cm) were done in 512 men (94%) and 26 women (6%); 152 (35%) had unilateral and 286 (65%) had bilateral CIAAs. Group 1 comprised 377 patients (633 CIAAs) with current or previously repaired abdominal aortic aneurysm (AAA). Group 2 comprised 15 patients (24 CIAAs) with associated internal iliac artery aneurysm (IIAA). Group 3 comprised 46 patients (58 isolated CIAAs). Median expansion rate of 104 CIAAs with at least two imaging studies was 0.29 cm/y; hypertension predicted faster expansion (0.32 vs 0.14 cm/y, $P =$ .01). A total of 175 patients (29%) were symptomatic. The CIAA ruptured in 22 patients (5%, median, 6 cm; range, 3.8-8.5 cm), and the associated AAA ruptured in 20 (4%). Six (27%) ilioiliac or iliocaval fistulas developed. Repairs were elective in 396 patients (90%) and emergencies in 42 (10%). OR was performed in 394 patients (90%) and EVAR in 44 (10%). The groups had similar 30-day mortality: 1% for elective, 27% for emergency repairs ($P < .001$); 4% after OR (elective, 1%; emergency, 26%), and 0% after EVAR. No deaths occurred after OR of arteriovenous fistula. Complications were more frequent and hospitalization was longer after OR than EVAR ($P < .05$). Mean follow-up was 3.7 years (range, 1 month-17.5 years). The groups had similar 5-year primary (95%) and secondary patency rates (99.6%). At 3 years, secondary patency was 99.6% for OR and 100% for EVAR ($P = .66$); freedom from reintervention was similar after OR and EVAR (83% vs 69%, $P = .17$), as were survival rates (76% vs 77%, $P = .70$).**

Conclusions: **The expansion rate of CIAAs is 0.29 cm/y, and hypertension predicts faster expansion. Because no rupture of a CIAA <3.8 cm was observed, elective repair of asymptomatic patients with CIAA ≥3.5 cm seems justified. Although buttock claudication after EVAR remains a concern, results at 3 years support EVAR as a first-line treatment for most anatomically suitable patients who require CIAA repair. Patients with compressive symptoms or those with AVF should preferentially be treated with OR. (J Vasc Surg 2008;47:1203-11.)**

Iliac artery aneurysms (IAAs) are the most frequent aneurysms after abdominal aortic aneurysms (AAAs), and common iliac artery aneurysms (CIAAs) are the most common IAAs.[1] Most CIAAs develop in patients with AAA, and isolated IAAs are rare, constituting only about 2% of all abdominal aneurysms.[2,3]

Similar to AAAs, CIAAs are more prone to rupture when they reach a critical size; unfortunately, data on the natural history of untreated CIAAs are scarce. McCready et al[1] observed a growth rate of 4 mm/y and recommended repair when they reached 3 cm in size. Santilli et al[4] studied the rate of growth of isolated IAAs, mostly CIAAs. IAAs <3 cm in size expanded at an average rate of 1.1 mm/y, whereas those >3 cm expanded by 2.6 mm/y. Because symptoms, including rupture, did not develop with IAAs <4 cm in diameter, the authors suggested repair for aneurysms >3.5 cm in size.[4]

Open surgical repair (OR) with prosthetic grafts has long been the gold standard of treatment of CIAAs, and results have improved during the past decades.[1,3-10] With the development of endovascular techniques, an increasing number of reports have been published on stent graft repair of CIAAs with good early- and mid-term results.[11-22] At some institutions, endovascular repair (EVAR) and not OR is now offered preferentially to patients with IAAs.[23]

The purpose of this study was to define expansion rate in a larger number of patients with CIAAs and to evaluate outcomes after OR and EVAR in patients with or without associated AAA in a contemporary series at a tertiary institution.

METHODS

The clinical records of patients with the diagnosis of CIAA seen at the Mayo Clinic, Rochester, Minnesota,

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Competition of interest: none.
Additional material for this article may be found online at www.jvascsurg.org.
Presented at the 2007 Vascular Annual Meeting of the Society for Vascular Surgery, Philadelphia, Pa, June 6-10, 2007.
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0741-5214/$34.00

doi:10.1016/j.jvs.2008.01.050

between January 1, 1986, and December 31, 2005, were retrospectively reviewed. The data of 438 patients who underwent interventions for 715 CIAAs were analyzed.

A CIAA was defined as a permanent localized dilatation ≥2.0 cm in size and an AAA ≥3.5 cm, measured by ultrasonography (US), computed tomography (CT) scan, magnetic resonance (MR) imaging, angiography, or documented by surgical records. The maximum transverse aneurysm diameter was recorded. Patients with interventions for CIAA were divided into three groups: group 1 included patients with CIAA who also had AAA, group 2 included patients with CIAA and internal iliac artery aneurysm (IIAA), and group 3 included those with isolated CIAA. In group 1, only patients who had at least one CIAA with a diameter of ≥3.5 cm were included, and treatment of the CIAA alone was justified. In groups 2 and 3, patients were included with a CIAA ≥2.0 cm in size. Patients with the diagnosis of common iliac artery pseudoaneurysms or dissections were excluded. Expansion rate of aneurysms was studied in patients who had ≥2 US or CT scans before repair.

Cardiac, pulmonary, and renal risk factors were documented using criteria of the Department of Veterans Affairs National Surgical Quality Improvement Program (NSQIP).[24] Criteria for high surgical risks were defined in our previous report.[25]

Indications for repair in group 1 included rupture or symptoms of CIAA, previous embolic events, or size ≥3.5 cm. In groups 2 and 3, seven patients with nine asymptomatic CIAAs underwent repair with aneurysm sized <3.5 cm, and 28 patients with 33 asymptomatic CIAAs ≥3.5 cm were treated. Criteria for EVAR (after 2001) were anatomic suitability and surgeon and patient preference. The most frequent techniques for OR are presented in Fig 1, *A*; excision, ligation, or endoaneurysmorrhaphy were also used selectively. In some patients, extra-anatomic ilioiliac or femorofemoral bypass was performed.

Endovascular repair included aortobiiliac stent grafts or straight iliac endografts (Fig 1, *B*), usually with embolization of the internal iliac artery (IIA) or IIAA. Bypass from the external iliac artery (EIA) or femoral artery to IIA was performed in some patients to preserve pelvic circulation.

Patients were asked to return at 3 months for physical examination and US imaging, and every 6 months afterwards. Patients with EVAR were monitored with CT scanning every 6 months. Patency and presence of endoleaks were determined by imaging studies. Follow-up information, including reinterventions, was obtained from the medical records and by mailed questionnaires. The study was approved by the Mayo Foundation Institutional Review Board.

Descriptive statistics, including means, standard deviations, ranges, and proportions were calculated as appropriate. The paired *t* test was used in right and left aneurysm size analysis. Patency, reintervention, and survival were calculated using the Kaplan-Meier method. Log-rank tests were used to compare survival and reintervention rates between groups as well as survival of our study cohort with the expected survival rate for an age- and sex-matched cohort from the United States population. Cox proportional hazards regression and multivariable analyses were used for survival comparisons. Analyses were performed using SAS 9 software (SAS Institute Inc, Cary, NC).

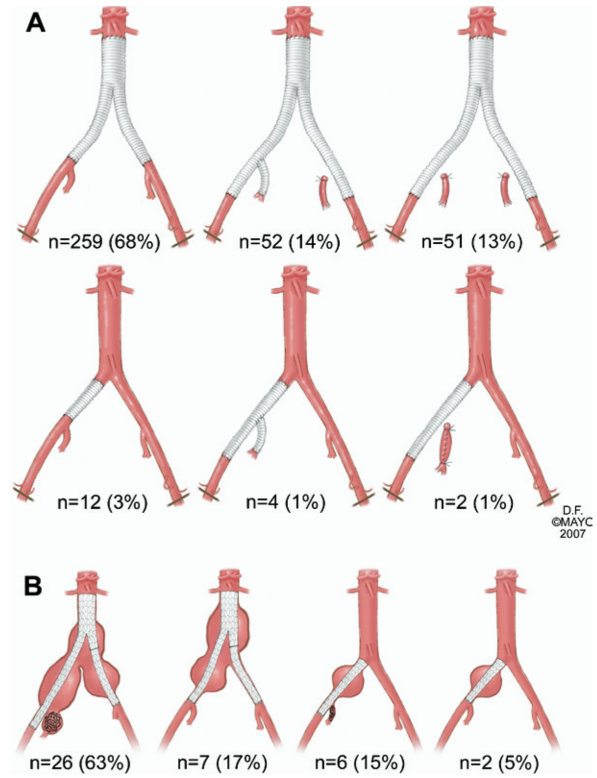

Fig 1. Interventions. **A,** Open repair with bifurcated or straight polyester graft in 380 patients. **B,** Endovascular repair with bifurcated or straight stent grafts in 41 patients.

RESULTS

Demographic data. Between 1986 and 2005, 1711 patients were diagnosed with 2637 CIAAs at the Mayo Clinic, Rochester, Minnesota. Of these, 438 underwent interventions (Table I) for 715 CIAAs, 382 right (53%), and 333 left (47%); 377 patients (86%) also had AAA, and 286 (65%) had contralateral CIAA. A total of 128 patients (29%) had IIAA (unilateral, 82; bilateral, 46), and 11 (3%) had external IAA (unilateral, 10; bilateral, 1).

Group 1 included 377 patients (86%) with 633 CIAAs (89%); 327 (87%) had concurrent AAA and 50 (13%) had previously repaired AAA. Group 2 included 15 patients (3%) with 24 CIAAs (3%). Group 3 included 46 patients (11%) with 58 CIAAs (8%), of which 12 patients (25%) had bilateral CIAAs compared with 265 in group 1 (70%) and nine in group 2 (60%; $P < .001$). Of 11 patients with external IAA, 10 were classified into group 1 and one into group 2; six of these patients had IIAA. IIAA was more frequent in patients with bilateral vs unilateral CIAAs (37% [105 of 286] vs 15% [23 of 152], $P < .001$).

Table I. Demographic data and risk factors of 438 patients with common iliac artery aneurysms

Variable	*Value*
Patients, No. (%)	438 (100)
Sex, No. (%)	
Male	412 (94)
Female	26 (6)
Age, years	
Mean ± SD	72 ± 7
Median (range)	73 (47-91)
Cardiovascular risk factors, No. (%)[a]	213 (49)
Pulmonary risk factors, No. (%)[a]	121 (28)
Renal risk factors, No. (%)[a]	42 (10)
Hypertension, No. (%)	304 (69)
Diabetes mellitus, No. (%)	45 (10)
Current smokers, No. (%)	96 (22)

[a]As defined by the National VA Surgical Quality Improvement Program.[24]

Imaging studies. Of 715 CIAAs, 699 (98%) had imaging studies: 535 (77%) had CT scan or CT angiography, 326 (47%) had US, 229 (33%) had contrast aortography, and 29 (4%) had MR angiography. Size was available for 668 CIAAs (93%), and the median diameter was 4 cm (range, 2-13 cm; Appendix Table I, online only). In patients with bilateral CIAAs, the right aneurysm was larger than the left (median, 4.2 cm [range, 2-13 cm] vs 3.6 cm [range, 2-9 cm] $P < .001$). Median diameter of 22 ruptured CIAAs was 6 cm (range, 3.8-8.5 cm; Appendix Table I, online only). The smallest aneurysm that ruptured was 3.8 cm. Six CIAAs (27%; median, 5 cm [range, 3.8-8.5 cm]), all in group 1, ruptured into the iliac vein or inferior vena cava (right, 5; left, 1).

Expansion rate. Seventy-two patients with 104 CIAAs had at least two US or CT scans. Median expansion rate was 0.29 cm/y (Table II). Hypertension predicted faster expansion (0.32 cm/y vs 0.14 cm/y, $P = .01$).

Clinical presentation. A total of 125 patients (29%) were symptomatic; abdominal or lower quadrant pain was the most frequent symptom (56%; Table III). Two patients had acute deep vein thrombosis (DVT), and 11 had chronic DVT. Forty-five aneurysms ruptured.

Intraoperative data. Repairs were elective in 396 patients (90%). Emergency repair was done in 42 (10%) for aneurysm rupture in 40 patients (OR, 18 ruptured CIAAs, 18 ruptured AAAs, 3 ruptured pseudoaneurysms; EVAR, 1 ruptured AAA), and two symptomatic CIAAs. Elective repair was done in five patients with ruptured aneurysms, comprising three arteriovenous fistulas (AVFs,) one iliac, and one AAA rupture.

Open repair was done in 394 patients (90%) for 648 (91%) CIAAs; 384 patients also had revascularization of the affected limb; 380 had bifurcated or straight polyester grafts (Fig 1, *A*), 3 had a femorofemoral crossover graft placed, and 1 patient had CIAA resection with reanastomosis of the common to external IA. For the remaining 10 patients, 7 had previous AAA repair with aortobifemoral bypass grafts, endoaneurysmorrhaphy of CIAA was performed on 6 and ligation on 1; 1 patient had one-stage CIAA ligation and ipsilateral external hemipelvectomy. Two patients with ruptured AAA died during emergency abdominal exploration.

The IIA was revascularized in 56 cases with separate bypass grafts. The inferior mesenteric artery (IMA) was reimplanted in 40 patients. Seven patients (group 1, 2%) underwent thoracolaparotomy for repair of an associated thoracoabdominal aneurysm.

Endovascular treatment was performed on 44 patients (10%), 41 with stent grafts (Fig 1, *B*) and 3 with coil embolization alone; 43 had elective, and 1 had emergency repair. Stent grafts used included 30 AneuRx (Medtronic Inc, Santa Rosa, Calif), 7 Gore Excluder (W. L. Gore & Associates Inc, Flagstaff, Ariz), 1 Zenith (Cook Medical Inc, Bloomington, Ind), 1 Ancure (Guidant Corp, Indianapolis, IN), 1 Wall graft (Boston Scientific Corp, Natick, MA), and 1 AneuRx-Zenith combination. Thirty-two patients had IIA (n = 19) or IIAA (n = 13) coil embolization, 10 preoperatively and 22 intraoperatively (Fig 1, *B*). Three patients with EVAR underwent IIA reconstruction with EIA to IIA bypass (n = 2) or superficial femoral artery to IIA bypass (n = 1). There was no conversion to OR.

Simultaneous IIAA exclusion was performed in 97 of 128 patients (76%) for 109 of 174 IIAAs (63%), consisting of ligation in 44, endoaneurysmorrhaphy in 40, excision in 12, and embolization in 13. Median operative time was 271 minutes (range, 24-710 minutes) and was longer with OR at 285 minutes vs EVAR at 172 minutes ($P = .002$).

Histologic study was performed in 291 patients (66%); of which 280 (96%) had degenerative atherosclerosis, eight aneurysms (3%) were inflammatory and fibromuscular dysplasia (FMD) was present in three (1%). According to imaging, surgical and pathological records, 21 patients (5%) had inflammatory CIAA.

Early Results

Mortality. The 30 day mortality was 3% (n = 15), occurring after four elective (1%) and 11 (27%) emergency ORs ($P < .001$). There was no difference among groups (group 1, 12 [3%]; group 2, 0; group 3, 3 [7%], $P = .93$). No deaths occurred after OR of iliac AVF and EVAR. For elective repair there was no significant difference in mortality between high- and low-risk patients at 30 days (2% vs 1%, $P = .30$).

Morbidity. Major complications occurred in 23% of patients, more frequently after emergency than elective repair ($P < .05$; Table IV). The groups had similar morbidity at 30 days. Pulmonary complications were significantly more frequent in high-risk patients (21% vs 13%, $P = .03$). Clinically significant ischemic colitis developed in four patients (1%), two after emergency, and two after elective repairs; none had revascularization of the IIAs, and both IIAs were ligated in one patient. Two patients had ischemic injury to the spinal cord, one after thoracoabdominal repair, the other after elective OR using a bifurcated polyester graft with ligation of both IIAs and reimplantation of IMA.

Table II. Median expansion rate of 104 common iliac artery aneurysms in 72 patients[a]

	Expansion rate in cm/y (number of aneurysms)				
Aneurysm type	*<2.5 (23)*	*2.5-2.9 (28)*	*3.0-3.4 (31)*	*≥3.5 (22)*	*Overall (104)*
CIAA					
With AAA	0.26 (22)	0.26 (26)	0.31 (26)	0.30 (20)	0.27 (94)
No AAA	0.72 (1)	0.84 (2)	0.36 (5)	1.78 (2)	0.40 (10)
Overall	0.26	0.26	0.32	0.31	0.29

CIAA, common iliac artery aneurysm; *AAA,* abdominal aortic aneurysm.
[a]P = .48 between CIAA with AAA and without AAA or between size groups.

Table III. Clinical presentation of 438 patients with common iliac artery aneurysms

	Group 1, No. (%)	*Group 2, No. (%)*	*Group 3, No. (%)*	*Overall, No. (%)*
Total patients	377	15	46	438
Asymptomatic	277 (71)	8 (53)	28 (61)	313 (71)
Symptomatic	100 (29)	7 (47)	18 (39)	125 (29)
Abdominal/lower quadrant/back pain	61 (16)	3 (20)	6 (13)	70 (16)
Claudication	22 (6)	2 (13)	9 (20)[a]	33 (8)
Lower extremity edema[b]	53 (8)[b]	1 (4)[b]	8 (14)[b]	62 (9)[b]
Urinary symptoms	6 (2)	0	1 (7)	7 (2)
Rupture	36 (10)	4 (27)	5 (11)	45 (10)[c]
CIAA rupture	14 (4)	4 (27)[a]	4 (9)	22 (5)
AAA rupture	20 (5)	0	0	20 (4)
False aneurysm rupture	2 (1)	0	1 (2)	3 (1)[d]

AAA, abdominal aortic aneurysm; *CIAA,* common iliac artery aneurysm; *Group 1,* CIAA with current or previously repaired AAA; *Group 2,* CIAA with IIAA; *Group 3,* isolated CIAA.
[a]$P < .05$ among 3 groups.
[b]Calculation based on per limb: group 1, 633; group 2, 24; group 3, 58; overall, 715.
[c]One contained AAA rupture and one arteriovenous fistula was asymptomatic.
[d]Two aortic pseudoaneurysms and one external iliac artery pseudoaneurysm ruptured.

Patency. Primary and secondary patency rates at 30 days were 99.4% ± 0.3% and 100%, respectively. There was no difference among groups or between OR and EVAR. Two prosthetic grafts and two stent grafts thrombosed. Both were recanalized with thrombectomy (n = 2) or thrombolysis (n = 2), with an additional stent graft placement in one.

Endoleak. Thirteen patients (31%) had endoleak at discharge (type I, 1; type II, 9; both, 1; type IV, 1; unknown, 1), resulting in 90% freedom from non-type II endoleak and 78% freedom from type II endoleak.

Hospital length of stay. Median ICU and hospital lengths of stay were shorter for patients with EVAR (0 and 2 days) vs those with OR (3 and 10 days, $P < .001$). The days were similar in all 3 groups.

Late Results

Survival. Five-year survival rate was 65% ± 3%, not different between groups, but less than the expected 76% survival of the United States population matched for age and sex ($P < .001$). Survival was higher in patients with elective vs emergency repair (68% ± 3% vs 34% ± 8%, $P < .001$). Three-year survival was similar in patients with OR and with EVAR (Fig 2). Univariate analysis revealed rupture was the best predictor of decreased survival ($P < .001$; Appendix Table II, online). In multivariate analysis, emergency intervention, chronic obstructive pulmonary disease (COPD), and age remained significant predictors ($P < .01$), with respective hazard ratios (95% confidence intervals) of 2.55 (1.75-3.70), 1.96 (1.49-2.56), and 153 (1.19-1.98). No late rupture of an aneurysm was identified.

Patency. During a mean follow-up of 3.7 years (range, 1 month-17.5 years), 5-year primary and secondary patency rates for the entire cohort were 95% ± 1% and 99.6% ± 0.3%, respectively. There was no difference in patency among three groups. Five-year primary patency rates after OR were higher with elective (97% ± 1%) vs emergency repair (73% ± 12%, P = .03; Appendix Fig 1, online only). At 3 years, primary patency rates were equivalent for OR (97% ± 1%) vs EVAR (95% ± 3%, P = .11; Appendix Fig 2, online only), and there was also no difference between secondary patency, at 99.6% ± 0.3% for OR and 100% for EVAR, respectively (P = .66).

Endoleak. Eight of 41 patients (20%) with stent grafts had endoleak at the time of the last imaging study (median, 1.6 years; range, 1.7 month-4.8 years). There were four type II endoleaks, three small distal type I endoleaks, and one endoleak of unknown origin.

Reinterventions. During a mean follow-up of 5.4 years (range, 1 month-19.9 years), 43 patients (10%) underwent 51 reinterventions (OR, 35 [9%]; EVAR, 8, [18%], P = .06), of which 25 were vascular and 26 nonva-

Table IV. Early complications

Complications	*Open repair (n = 389[a]), No. (%)*		*Endovascular repair (n = 44), No. (%)*		*Overall, No. (%)*
	Elective	*Emergency*	*Elective*	*Emergency*	
Patients, No.	353	36[a]	43	1	433[a]
Systemic morbidity					
Cardiac complications	38 (11)	12 (33)[b]	2 (5)	0	52 (12)
Myocardial infarction	6 (2)	5 (14)[b]	0	0	11 (3)
Pulmonary complications	46 (13)	19 (53)[b]	0[c]	0	65 (15)
Pneumonia	21 (6)	12 (33)[b]	0	0	33 (8)
Pulmonary embolism	3 (1)	1 (3)	0	0	4 (1)
Renal complications	14 (4)	6 (17)[b]	0	0	20 (5)
Acute renal failure	4 (1)	4 (11)[b]	0	0	8 (2)
Ileus	17 (5)	4 (11)	0	0	21 (5)
Deep vein thrombosis	6 (2)	2 (6)	0	0	8 (2)
Lower limb ischemia	6 (2)	0	0	0	7 (2)
Ischemic colitis requiring operation	2 (1)	2 (6)[b]	0	0	4 (1)
Wound complications					
Wound infection	6 (2)	3 (8)[b]	1 (2)	0	10 (2)
Wound Dehiscence	10 (3)	2 (6)	1 (2)	0	13 (3)
Graft failure	2 (1)	0	2 (5)	0	4 (1)
Total	345	34	40	1	422

[a]Five intraoperative deaths were excluded.
[b]$P < .05$ vs elective repair.
[c]$P < .05$ vs open repair.

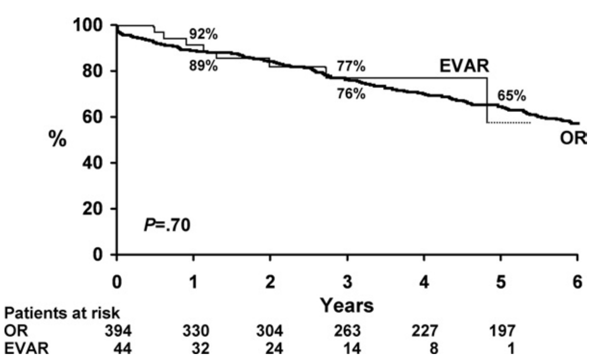

Fig 2. Kaplan-Meier analysis shows survival of 438 patients after open (OR) and endovascular (EVAR) repair of common iliac artery aneurysms. The *dotted line* indicates standard error >10%.

scular. The 5-year freedom from reinterventions was 79% ± 2% (89% ± 2% for vascular and 87% ± 2% for nonvascular complications). There was no difference among groups or between OR and EVAR at 3 years (all-cause, 83% ± 2% vs 69% ± 9%, $P = .17$; vascular, 92% ± 2% vs 79% ± 8%; $P = .13$; Appendix Fig 3, online only). Freedom from reinterventions was higher in patients with elective vs emergency repair after OR at 2 years (all-cause: 87% ± 2% vs 72% ± 8%, $P = .002$; vascular: 95% ± 1% vs 82% ± 7%, $P = .003$).

There was no difference in graft patency or reinterventions in patients who underwent OR before or after the endovascular era (1986-2000: 312 patients, 503 CIAAs; 2001-2005: 82 patients, 145 CIAAs).

Buttock claudication. Buttock claudication was reported in 36 of the 433 survivors (8%). The incidence was 5% (21 of 389) after OR and 34% (15 of 44) after EVAR ($P = .001$). The incidence in OR patients was 27% (26 of 98, per limb) in those who underwent IIA ligation. In nine patients with bilateral IIA ligation, five had bilateral and two had unilateral buttock claudication; only two were asymptomatic. In 35 patients with IIA or IIAA embolization, buttock claudication was present in 15 of 33 patients (45%, per limb). There was no significant difference in buttock claudication between patients with IIA ligation and those with IIA embolization ($P = .05$).

Most patients reported improvement in symptoms during follow-up examinations, and no patient required additional intervention for claudication.

DISCUSSION

CIAAs occur most frequently in elderly men. The prevalence of male patients ranges from 81% to 100%, with a mean age between 62 and 75 years.[1,4,8,9,13,23,26] About 20% of patients with AAA have a CIAA,[27] and isolated CIAAs are rare. In a Danish study that screened 4176 men for AAA, the prevalence of CIAA >3.5 cm in men between the ages of 65 and 73 was 0.17%; isolated CIAAs occurred in 0.05%.[28]

Patients with CIAAs frequently have aortic and other IAAs. Richardson and Greenfield[9] observed multiple aneurysms in 67% of the patients with IAAs. In our series, 86% of the patients with CIAA had AAA and 65% had contralateral CIAA. Isolated CIAAs had less (26%) contralateral CIAAs than those with associated AAA (70%). Most CIAAs are degenerative atherosclerotic aneurysms; inflammatory aneurysms have been observed in 3% to 19% of the cases.[29-31]

Growth of CIAAs has been frequently unpredictable. Kasirajan et al[32] noted no growth of seven isolated CIAAs, measuring 2 to 2.5 cm in diameter, monitored for 50 months.

Santilli et al[4] observed 323 IAAs for a mean of 31.4 months, and no expansion of the aneurysms was recorded in 37.5%; those >3 cm in size grew at an average of 2.6 mm/y. Median growth rate in our study was 0.29 cm/y, and those >3 cm in size grew by 3.2 mm/y. Hypertension was correlated with growth. Limitations of our data are that expansion rate could only be measured in 15% of the treated iliac aneurysms (n = 104). However, 51% of aneurysms (n = 53) in our series monitored for growth were >3 cm; whereas in the Santilli series, 12% (n = 40) were ≥3 cm, a variable likely responsible for the different findings.

A 3-cm CIAA has been considered for repair by most authors because of an increasing risk of developing symptoms, including rupture of the aneurysm.[1,4,6,8-10,28,32-34] Most ruptured IAAs are usually much larger, however. McCready et al[1] noted mean size of both symptomatic and ruptured IAAs was 7.8 cm. Lowry and Kraft[3] found mean diameter of ruptured IAAs was 7.5 cm, and Richardson and Greenfield[9] observed that sizes of ruptured IAAs ranged from 3.5 to 18 cm. In our series, the median diameter of ruptured CIAA was 6 cm, three were <5 cm, and no aneurysm <3.8 cm in diameter ruptured. It appears that asymptomatic CIAAs <3.5 cm in size can be safely observed. This number in high-risk patients can be 4 cm, as suggested by Santilli et al.[4]

IAAs are frequently symptomatic, and the risk of rupture in series with isolated IAAs was high. In a review of the literature that included 367 patients with 500 isolated IAAs, Krupski et al[8] found 62% were symptomatic and 29% ruptured. Symptoms include right lower quadrant pain, renal dysfunction, DVT, and rectal or perineal pain. Thrombosis and embolism will result in hip or leg claudication. In our series, 29% of CIAAs were symptomatic and 5% ruptured. Patients with isolated CIAAs had a 9% risk of rupture.

A CIAA rupture is usually a life-threatening emergency that can lead to hemorrhagic shock and death without intervention. Rupture of an associated AAA can also occur in patients with CIAA, as it did in half of the patients we operated on emergently. Rupture of the CIAA into the iliac vein or inferior vena cava results in AVF, and some of these without retroperitoneal hemorrhage occasionally remain stable for days or even weeks. Presentations include lower limb swelling, a continuous abdominal bruit, abdominal pain, decreased pedal pulses, heart failure, and renal dysfunction. On CT angiography, immediate filling of dilated iliac veins and the inferior vena cava is evident. Open repair includes control of the fistula from within the sac of the aneurysm with digital compression, avoiding pulmonary embolization of debris from the aneurysm sac (Fig 3). Venous bleeding can usually be controlled with a balloon catheter for direct suture closure of the defect, and the aneurysm is repaired with a prosthetic graft.[35] Successful repair of abdominal AVF with EVAR has also been reported.[36-38]

Open repair of CIAA includes the use of bifurcated or straight polyester grafts placed through a transperitoneal or retroperitoneal approach. Open repair can be challenging because of previous abdominal surgery or deep location of the aneurysm, especially in obese patients. Before OR of

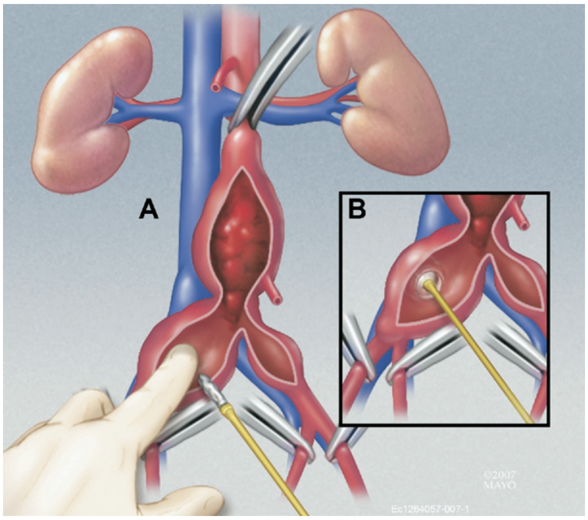

Fig 3. Drawing shows open repair of an ilioiliac arteriovenous fistula. **A,** Digital compression of the fistula controls venous bleeding. **B,** Placement of a venous thrombectomy catheter and suture closure of the fistula before graft repair.

inflammatory aneurysms, placement of ureteral stents is helpful. Simultaneous AAA, CIAA, and IIAA repair is performed if concomitant aneurysms are present. Preservation of flow through at least one IIA is important and is done using an interposition graft from the iliac limb of the polyester graft. If the IIAs have to be oversewn, or unilateral ligation is performed in the face of contralateral IIA occlusion, reimplantation of the IMA into the aortic graft is advised. Unfortunately, collateral circulation may not always be sufficient to prevent ischemic colitis despite IMA reimplantation, as was the case in two of our patients.

Results of ORs have continuously improved in the past decades. In a collected series of 320 operations performed between 1985 and 2001, mortality in elective repair was 5%, with an emergency mortality rate of 40%.[26] In a seminal paper on OR of 19 isolated IAAs, Krupski et al[8] reported no deaths and a single major complication (5%). Our series of 438 patients had an elective mortality rate of 1%, but major complication rates were high at 23%. Mortality for emergency OR was 27%. Correct early diagnosis, preoperative planning and a systematic open operative approach that includes retroperitoneal repair for unilateral disease, revascularization of at least one IIA, and the liberal use of IMA reimplantation, as suggested by Krupski,[8] can decrease the risk of complications.

No deaths occurred in our patients who underwent OR for AVF. Because most aortocaval or ilioiliac AVFs are caused by unusually large aneurysms, palpation of the inferior vena cava or iliac veins before aortic cross clamping is strongly advised: a thrill indicates arteriovenous shunting.

Endovascular repair has emerged as a safe and minimally invasive technique for repair of CIAAs. It has become an attractive, low-risk option for those who are anatomically suitable for stent graft repair and do not present with compressive symptoms. Most patients require bifurcated stent graft repair with embolization of the IIA or the IIAA.

Durability, anastomotic endoleak, stent graft thrombosis, high cost, and maintaining circulation to the IIA remain potential problems. The rate of perioperative complications in a recent review was 20% (range, 10%-32%). Anastomotic endoleak occurred in 4% of the patients.[26] In a series of 28 isolated IAAs treated with EVAR, Parsons et al[39] reported four (12%) complications, that included embolization (n = 1), wound dehiscence (n = 2), and mucosal ischemia (n = 1). One late rupture required conversion to OR. Patency at 3 years was 86%.

Concerns about the need to occlude the IIA during EVAR have been raised by Krupski et al[8] since a multicenter study reported a technical failure rate of 19% and an adverse event rate of 27%.[40] Results in the past decade, however, improved continuously, and a review of 117 isolated IAAs[26] treated with EVAR in 106 patients revealed a 1% mortality rate, with no deaths reported in studies published after 1996. We had no deaths and found shorter ICU and hospital lengths of stay and fewer major complications after EVAR than after OR. At 3 years, the reintervention rate was not higher after EVAR, similar to the results found by others,[22] and there was no survival advantage for OR.

Embolization of unilateral IIA can be performed with low risk of serious adverse effects, although the high incidence of buttock claudication after EVAR, which was 45% in our patients and 31% in another recent series,[22] remains a concern. Most patients, however, tolerate symptoms well and improve with time, even to a degree of resolution of symptoms.[22] The incidence of buttock claudication and pelvic ischemic complications after bilateral IIA occlusion is very high,[8,40] however, and patients with a contralateral IIA who are treated with EVAR should also undergo ipsilateral IIA revascularization using either endovascular or open surgical techniques, such as retroperitoneal IIA bypass using the common femoral or EIA as inflow. Early results of branched stent graft repairs of IAAs have been published,[13,16,19-23,34,39,40] and more frequent use of these devices to assure pelvic perfusion can be expected in the future.

It is also noteworthy that IIA revascularization cannot always be performed during OR: one-third of our patients did not undergo IIA revascularization. When a patent ipsilateral iliac artery was ligated during surgery, the incidence of buttock claudication was 27%.

Endovascular repair for ruptured CIAAs is attractive and it is easy to predict that this will be the procedure of choice in anatomically suitable patients. At this time, OR is the main treatment option of CIAAs that cause compressive symptoms because most IAAs do not decrease in size after EVAR.[39]

Our review has the usual limitations of a large retrospective study. This is a single-center experience with CIAAs, including those who presented with associated AAAs. It was interesting to note, however, that subgroup analysis did not reveal differences in complications or survival of patients with or without AAA.

CONCLUSION

Our study confirmed that CIAAs are frequently associated with AAAs. We found the expansion rate of CIAAs was 0.29 cm/y and hypertension predicted faster expansion. Because no rupture of a CIAA <3.8 cm was observed, elective repair of good risk asymptomatic patients with CIAA >3.5 cm is justified. Both OR and EVAR can be performed with low mortality in elective patients, but early complications and hospital days are higher after OR than after EVAR. Survival and reintervention rates were similar between OR and EVAR at 3 years. Although the high incidence of buttock claudication after EVAR remains a concern, these data support EVAR as a first-line treatment for most anatomically suitable patients who require repair of CIAA. Patients with compressive symptoms or those with AVF should preferentially be treated with OR.

We thank Dr. Haraldur Bjarnason for his participation in some of these operations, Kristine Thomsen for her data analysis, and Marcia Simonson for her assistance.

AUTHOR CONTRIBUTIONS

Conception and design: YH, PG, AD, MK, GO, MM, TB
Analysis and interpretation: YH, PG, TH
Data collection: YH
Writing the article: YH, PG, TH
Critical revision of the article: YH, PG, TH, AD, MK, GO, MM, TB
Final approval of the article: YH, PG, AD, MK, TH, GO, MM, TB
Statistical analysis: TH, YH, PG
Obtained funding: YH, PG
Overall responsibility: PG

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Submitted Aug 6, 2007; accepted Jan 25, 2008.

Additional material for this article may be found online at www.jvascsurg.org.

DISCUSSION

Dr Richard Cambria (Boston, MA). Dr Huang, Dr Gloviczki, congratulations on a great series. Obviously, the Program Committee was impressed. It's one of the largest series that I know of in the literature. And I'm happy to comment, since some of your data reinforces my biases. Over the years seeing patients who had been recommended to have repair of 25-mm iliac aneurysms is, of course, a common observation in vascular surgeons' offices. So I have a question. And your talk, of course, was beautifully illustrated. I predict that the finger in the fistula slide will become a classic.

My question is about your conclusion. Your conclusion was that repair of aneurysms greater than 3.5 cm is justified. My bias about these aneurysms, that they generally tend to be large before they rupture, is I think corroborated by your data. So what will be your take-home message about a recommendation for size threshold for repair?

Dr Peter Gloviczki: Thank you very much, Dr Cambria. Your question is obviously an excellent question, because most of the aneurysms that ruptured were greater than 5 cm in size. So we tried to define in our experience and in the literature what would be the size in good-risk asymptomatic patients that warrant repair. And since, again, we found no ruptures in aneurysms less than 3.8 cm in size, but we found an aneurysm, and others have found an aneurysm, in that size range, that's why we think that the original data that was recommended by Dr Santilli of 3.5 cm can be currently accepted as a critical size for good-risk surgically fit patients for repair of common iliac artery aneurysms.

Dr Anil Hingorani (Brooklyn, NY). Did you notice any external iliac artery aneurysms in your series? Because they have been reported very rarely in the literature.

Dr Gloviczki: We had 11 patients in this series in whom the diagnosis of external iliac artery aneurysm was given. Most of them, frankly, were extensions of common iliac artery aneurysms; therefore, we just decided, as many did in the literature, to disregard patients who had external iliac artery aneurysm.

There was one patient who did not have internal iliac artery aneurysm with a common iliac artery aneurysm but had an external iliac aneurysm. So I would say external iliac artery aneurysm continues to be very rare. Some of them are false aneurysms after a previous repair, but we did not specifically actually look at them because of the very small group.

Dr Daniel Reddy (Detroit, Mich). Particularly with this large experience with iliac aneurysms, I am interested to hear whether the patients experienced any buttock claudication, particularly in the more recent patients, that may have had embolization.

Dr Gloviczki: That is an excellent point, because obviously that is why you may think that an open repair would be better for your patients than an endovascular repair.

We had many surprises when we looked up the data of this study. And one of them was clearly that we found actually pretty high number of buttock claudication in those patients, too, who underwent open repair. Open repair doesn't necessarily mean that your patient had internal iliac artery revascularization. Indeed, 29% of the open repair had ipsilateral internal iliac artery ligated at some level.

So buttock claudication was significant. But again, you are treating your patient with a potentially life-threatening condition, and you have to make a decision whether buttock claudication is a reasonable alternative to risk of the rupture. And usually it is.

One-third of the patients who underwent ligation—and we had follow-up information almost of 100 patients—had buttock claudication who had ligation of the ipsilateral internal iliac artery. Patients who had bilateral internal iliac artery ligation had buttock claudication in 80%. About 45% of our patients who underwent endovascular repair with embolization had some degree of buttock claudication. So buttock claudication continues to be a problem. And I think, therefore, investigation to revascularize the internal iliac artery with endovascular technique should be continued.

Dr Steven Rivers (Bronx, NY). It seems like most of the patients did have associated more generalized aneurysmal disease. And I would assume that the treatment selection and the results were dictated largely, I mean not exclusively, but to some degree by the presence or absence of the abdominal aortic aneurysm component.

My question is, what is the current approach at the Mayo Clinic for a patient who presents with an asymptomatic isolated iliac artery aneurysm, would you recommend endografting as your first-choice procedure or would you still recommend open repair in a patient who was both physiologically and technically feasible for either modality?

Dr Gloviczki: I think you bring up an excellent point that, indeed, more than 80% of the patients have associated aortic aneurysms. Now, we decided to include only those patients from that group who had large, greater than 3.5 cm, iliac artery aneurysms. And one of the reasons is that we didn't want Dr Huang to review several thousands of patients who had smaller iliac artery aneurysms. So that is the comment on the combined group.

Patients who have isolated iliac artery aneurysms currently, I would say, based on the data that we have, we strongly consider offering as a first line of treatment endovascular repair. But we also will take into consideration the associated aneurysms. We take into consideration the data that are available out there for aortic aneurysms. But more so for iliac than for aortic aneurysm do we now consider endovascular repair as the primary treatment.

Dr Harry Schanzer (New York, NY). In the patients that have the unilateral common iliac aneurysm and you are planning an endovascular repair, how often do you put a single tube or you have to go for a bifurcation?

Dr Gloviczki: As you could see, we only had 8 patients who had a single tube. And of the 8, we only had 2 where we could place this tube into the common iliac artery. So I would suggest that it's rare that you have a suitable or excellent proximal and distal endings in the common iliac artery. In 75% we have to go into the external iliac artery and, again, over 80% will require bifurcated repair.

Appendix Table I (online only). Size distribution of 668 common iliac artery aneurysms

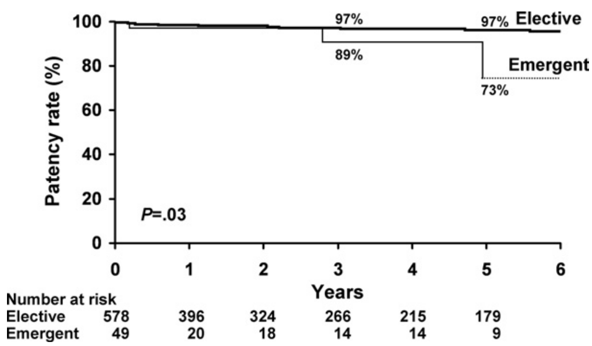
Presentation	*Total*	*<2.4 cm, No. (%)*	*2.5-2.9 cm, No. (%)*	*3.0-3.4 cm, No. (%)*	*3.5-3.9 cm, No. (%)*	*4.0-4.4 cm, No. (%)*	*4.5-4.9 cm, No. (%)*	*>5 cm, No. (%)*
Asymptomatic	495	41 (8)	47 (9)	46 (9)	106 (21)	108 (22)	45 (9)	102 (21)
Symptomatic[a]	158	8 (5)	14 (9)	19 (12)	33 (21)	33 (21)	14 (9)	37 (23)
Rupture	15	0	0	0	1[b] (7)	1 (7)	1 (7)	12 (80)
Total[c]	668	49 (7)	61 (9)	65 (10)	138 (21)	143 (21)	61 (9)	163 (24)

[a] $P = .79$ vs asymptomatic presentation.
[b] 3.8 cm.
[c] Sizes of 47 common iliac artery aneurysms were not available.

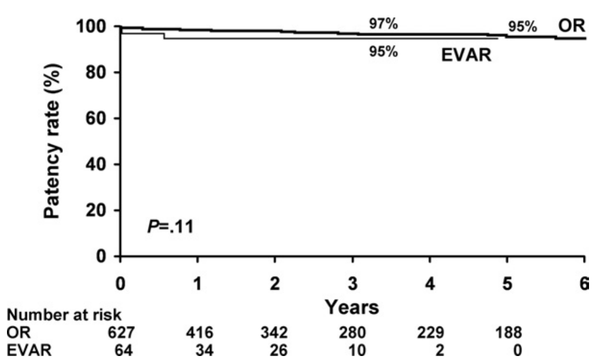
Appendix Table II (online only). Univariate analysis of risk factors predicting survival for 438 patients with common iliac artery aneurysms repair

Variable	*HR*	*95% CI*	*P*
CIAA rupture	2.81	1.76-4.50	<.001
Urgency (elective vs emergency)	2.37	1.63-3.44	<.001
COPD	1.87	1.43-2.44	<.001
High surgical risk	1.60	1.21-2.11	<.001
Age ≥73 y (median)	1.50	1.16-1.93	.002
Age, per 1 year	1.04	1.02-1.06	<.001
Diabetes mellitus	1.41	0.96-2.06	.08
Coronary artery disease	1.21	0.94-1.56	.14
AAA rupture	1.10	0.60-2.01	.77
Concomitant or repaired AAA	1.06	0.75-1.51	.73
Sex (male vs female)	1.02	0.60-1.72	.94

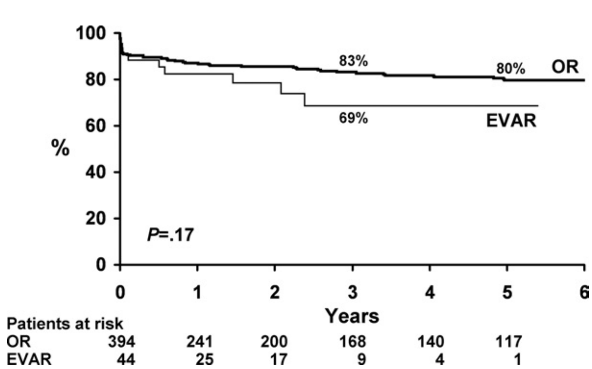
AAA, abdominal aortic aneurysm; *CI,* confidence interval; *CIAA,* common iliac artery aneurysm; *COPD,* chronic obstructive pulmonary disease; *HR,* hazard ratio.



Appendix Fig 1 (online only). Primary graft patency of 627 open emergency and elective common iliac artery aneurysm repairs. The *dotted line* indicates standard error >10%.



Appendix Fig 2 (online only). Primary patency of 691 common iliac artery aneurysm repairs CIAA repairs by open (OR) vs endovascular (EVAR) techniques. The standard error <10% for all data points.



Appendix Fig 3 (online only). Freedom from reinterventions for patients undergoing open (OR) and endovascular aneurysm repair (EVAR). Standard error <10% for all data points.