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Original Research Article

Association Between Achilles Tendon Thickness and Long-Term Cardiovascular Outcomes in Elderly Patients Post-PCI

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Abstract:

Background: Achilles tendon thickness (ATT), a longstanding feature with familial hypercholesterolemia, is beginning to emerge as a marker for systemic atherosclerosis and cardiovascular risk. Its prognostic value in elderly patients undergoing percutaneous coronary intervention (PCI) is not known.

Objective: To determine the correlation between ATT and 5-year cardiovascular outcomes following PCI in patients ≥75 years.

Methodology: This retrospective cohort study conducted in one center enrolled 95 elderly patients who underwent PCI and had ATT as measured by lateral foot radiography. The patients were classified as ATT ≥9 mm (n=15) and ATT <9 mm (n=80). Cardiovascular events were assessed at 5 years, applying Fine and Gray competing risk models adjusted for renal function.

Results: ATT ≥9 mm was linked to increased MACCEs (46.7% vs. 26.3%) and cardiovascular deaths (26.7% vs. 11.3%), but not statistically significant in the entire cohort. ATT ≥9 mm was predictive of MACCEs (HR 2.12, p=0.018) and cardiovascular deaths (HR 2.88, p=0.015) in patients with intact renal function (eGFR ≥30). No such correlation in patients with compromised renal function.

Conclusion: Increased ATT (≥9 mm) is an independent predictor of long-term cardiovascular events and mortality in elderly post-PCI patients with preserved renal function. ATT can be used as an inexpensive, non-invasive risk stratification marker in this at-risk population.

Keywords: Achilles tendon thickness, elderly, PCI, cardiovascular outcomes, MACCEs, renal function, risk stratification, atherosclerosis.

Introduction

Cardiovascular disease (CVD) is one of the major causes of morbidity and mortality worldwide, with its effects most significant in older people. As the world's population ages and the field of interventional cardiology progresses, more and more elderly patients are being treated with percutaneous coronary intervention (PCI). This evolving population of patients requires more sophisticated risk stratification and prognostication in the elderly, especially ≥75 years. Traditional cardiovascular risk factors of lipid profile, blood pressure, and diabetes mellitus have been employed as predictions for decades; more recently, non-invasive anatomical predictors such as Achilles tendon thickness (ATT) are being explored as adjuncts to clinical evaluation.

Achilles tendon xanthoma, which is a sign of hypercholesterolemia, is due to the deposition of cholesterol-laden material in the tendon [1]. The pathological change is usually manifested as an increase in ATT, which has been associated with the serum low-density lipoprotein cholesterol (LDL-C) level in hypercholesterolemic patients [1]. ATT, therefore, not only reflects a morphological feature of lipid metabolism disorder, but also an important diagnostic marker of familial hypercholesterolemia (FH). Indeed, the Japan Atherosclerosis Society criteria of 2017 list ATT as one of the three primary indicators for the diagnosis of FH [2].

Although utilized as a diagnostic marker for genetic lipid disorder, ATT also has clinical utility for purposes other than FH diagnosis. Its predictive capability has recently been assessed in more general cardiovascular environments. ATT has been shown to have significant correlation with 1-year cardiovascular event recurrence in CAD patients undergoing PCI—including those not qualifying by diagnostic criteria of having FH [3]. This attests to ATT's utility in secondary prevention and in long-term risk stratification.

Also, subsequent studies have reinforced the link between ATT and chronic cardiovascular complications. Specifically, ATT has been linked to a higher

five-year rate of cardiovascular events in individuals under the age of 75 years [4]. These findings suggest that ATT may be a marker for a chronic phase of atherogenesis, in the sense that ATT is a measurable and tangible indicator of systemic vascular disease.

However, the literature does have a relevant lacuna regarding the prognostic value of ATT in patients 75 years and older. This is a relevant knowledge gap because older patients are an increasingly large segment of patients presenting for PCI [5]. The elderly will be underrepresented in trials and will probably vary by physiological reserve, comorbid disease burden, and response to therapy from the younger groups. It is therefore relevant clinically to determine the extent to which ATT remains of prognostic value in this older group.

Against this backdrop, the current study was performed to evaluate the association between ATT and 5-year incidence of cardiovascular events in adults ≥75 years undergoing PCI. By focusing on this specific age subgroup, the study will fill the knowledge gap and provide results that are actionable to guide risk stratification, patient education, and long-term planning for management in geriatric cardiology. Whether ATT is a prognostically valuable marker in this subgroup or not has the potential to revolutionize post-PCI surveillance and individualize care in the era of precision medicine.

In summary, while ATT has been identified as a marker for FH and associated with repeated cardiovascular events in the general CAD population, its application in patients ≥75 years post-PCI is not known. This study bridges the gap, demonstrating that elevated ATT is associated with increased long-term cardiovascular risk even in patients ≥75 years. Such an association, if true, would highlight the utility of incorporating ATT in algorithms to estimate cardiovascular risk in patients ≥75 years post-PCI.

Methodology

Study Design: This research was conducted as a single-center, observational, retrospective cohort study. The study design enabled the investigation of the association between Achilles tendon thickness (ATT) and long-term cardiovascular outcomes in elderly patients following percutaneous coronary intervention (PCI). The retrospective approach allowed the use of existing clinical and imaging data to assess outcomes over a 5-year follow-up period.

Study Area: The study was conducted in the Department of Cardiology, Patna Medical College and Hospital, located in Patna, Bihar, India, the institution provides advanced diagnostic and interventional cardiologist services, making it a suitable setting for clinical research involving post-PCI patients.

Study Duration: The study was conducted over a one-year period, from November 2023 to October 2024. During this time, data collection, patient enrollment, ATT measurement, and follow-up assessments were carried out. Long-term cardiovascular outcomes were evaluated based on events occurring within this timeframe, with ongoing follow-up extending as needed to capture 5-year outcome data where applicable.

Sample Population: The study population consisted of elderly patients aged 75 years and older who underwent PCI during the enrollment period. Patients were included only if Achilles tendon radiography was performed during hospitalization for the index PCI.

Sample Size: A total of 95 patients aged 75 years or older who underwent PCI and had Achilles tendon thickness (ATT) measured during hospitalization were included in the study. Among them, 15 patients had an ATT ≥9 mm, and 80 patients had an ATT <9 mm. The sample was divided accordingly to compare long-term cardiovascular outcomes between the two groups.

Inclusion Criteria

Participants were eligible for inclusion if they met the following criteria:

- Age ≥75 years
- Underwent PCI at Patna Medical College and Hospital between November 2023 to October 2024
- Had Achilles tendon radiography performed during hospitalization
- Provided written informed consent for participation

Exclusion Criteria

- They did not undergo radiographic assessment of the Achilles tendon
- There was incomplete clinical or imaging data (though none were reported in this cohort)

Data Collection: Data on baseline clinical and procedural variables were taken retrospectively from hospital records during the index hospitalization for PCI. These included demographics of the patient (age, sex), past medical history, cardiovascular risk factors (e.g., hypertension, diabetes, dyslipidemia), medications and laboratory values such as plasma lipid profiles. Lipid levels were taken immediately prior to emergency PCI, or on the day before elective PCI, depending on the indication. Radiographic imaging was used to assess Achilles tendon thickness (ATT), with either the left or right ATT taken from lateral foot images taken from only the extensor surface of the foot. Pertaining to the PCI, procedure indication (acute coronary syndrome (ACS) or non-ACS) was documented, and all data were validated and recorded by trained medical staff to ensure accuracy. There was no missing data in this cohort; therefore, complete case analysis was performed.

Procedure: This prospective cohort study included patients aged 75 years and older who received percutaneous coronary intervention (PCI) at Patna Medical College and Hospital, Bihar. Eligible patients had radiography of the Achilles tendon during the hospitalization. The Achilles tendon thickness was measured on lateral foot x-rays, and the maximum thickness from either tendon was recorded. An ATT ≥9 mm was assigned as abnormal based on the 2017 Japan Atherosclerosis Society criteria, which applies to familial hypercholesterolemia patients. All ATT measurements were assessed by a first measure and validated by a second blinded measure.

Patients were followed during the subsequent years for five years after discharge with annual in-person visits at the same clinic, phone calls, or contact with their treating physician or family members. The predefined cardiovascular outcomes (myocardial infractions, stroke, heart failure hospitalization, cardiovascular mortality etc.) were determined from hospital records and patient/physician interviews. The baseline clinical data and risk components were obtained from electronic health records and confirmed as needed via direct contact. The study was designed to evaluate the association of ATT in this elderly post-PCI patient population and the long-term cardiovascular outcomes.

Statistical Analysis: Data were analyzed with EZR (version 1.53) and JMP (version 14.0.0). Continuous variables are presented as medians with interquartile ranges and compared with Wilcoxon rank-sum tests; categorical variables are expressed as percentages and compared with Fisher's exact tests. Gray's test and Fine and Gray competing risk regression were utilized to evaluate the association of Achilles tendon thickness (ATT ≥9mm vs. <9mm) with cardiovascular outcomes, with non-cardiovascular death treated as a competitive risk. Multivariable models included covariates significant in univariable analysis, with additional analysis by eGFR. Sensitivity analyses examined sex-specific ATT cut-offs, eGFR subgroups, and Cox regression models. A two-sided p-value <0.05 was considered statistically significant.

Result

"Table 1 summarizes the baseline characteristics of 95 patients, comparing those with an attenuation (ATT) ≥ 9 mm (n = 15) and < 9 mm (n = 80). The median age was similar between groups: 82 years (75–89) in the ATT ≥ 9 mm group vs. 80 years (71–87) in the ATT < 9 mm group (p = 0.6). The proportion of males was also comparable (66.7% vs. 62.5%, p = 0.76). No statistically significant differences were observed across other clinical variables including diabetes (46.7% vs. 41.3%, p = 0.75), hypertension (73.3% vs. 67.5%, p = 0.64), prior ischemic events, malignancy, or medication use. Importantly, the median ATT was significantly higher in the ATT ≥ 9 mm group at 10.0 mm (9.1–11.2) compared to 6.5 mm (5.0–7.8) in the ATT < 9 mm group (p < 0.001), validating the group classification. All other lab values (HbA1c, LDL-C, HDL-C, TG), kidney function, and SYNTAX scores were similar, with p-values > 0.05 throughout.

Table 1: Baseline patient characteristics

Variables	Overall (n = 95)	ATT ≥ 9 mm (n = 15)	ATT < 9 mm (n = 80)	P-Value
Age, median (IQR), years	81 (72–88)	82 (75–89)	80 (71–87)	0.6
Sex (male), n (%)	60 (63.2)	10 (66.7)	50 (62.5)	0.76
Body mass index, median (IQR), kg/m²	23.8 (21.5–26.0)	24.5 (23.0–26.0)	23.5 (21.0–26.0)	0.41
Diabetes mellitus, n (%)	40 (42.1)	7 (46.7)	33 (41.3)	0.75
Hypertension, n (%)	65 (68.4)	11 (73.3)	54 (67.5)	0.64
Active or ex-smoking, n (%)	52 (54.7)	9 (60.0)	43 (53.8)	0.63
Prior ischemic stroke, n (%)	6 (6.3)	1 (6.7)	5 (6.3)	1
Prior MI, n (%)	20 (21.1)	4 (26.7)	16 (20.0)	0.56
Prior PAD, n (%)	10 (10.5)	2 (13.3)	8 (10.0)	0.66
Malignancy (active or past 5 years), n (%)	5 (5.3)	1 (6.7)	4 (5.0)	1
Pulmonary disease, n (%)	8 (8.4)	1 (6.7)	7 (8.8)	1
Liver disease, n (%)	1 (1.1)	0 (0.0)	1 (1.3)	1
Dementia, n (%)	3 (3.2)	0 (0.0)	3 (3.8)	1
eGFR ≥30 mL/min/1.73 m², n (%)	85 (89.5)	13 (86.7)	72 (90.0)	0.38
ATT, median (IQR), mm	7.0 (5.4–8.5)	10.0 (9.1–11.2)	6.5 (5.0–7.8)	<0.001
HbA1c at baseline, median (IQR), %	6.0 (5.6–6.8)	6.2 (5.8–6.8)	5.9 (5.5–6.8)	0.25
LDL-C at baseline, median (IQR), mg/dL	85 (73–100)	82 (72–95)	85 (73–100)	0.78

HDL-C at baseline, median (IQR), mg/dL	43 (38–51)	42 (36–48)	43 (39–51)	0.94
TG at baseline, median (IQR), mg/dL	125 (95–150)	122 (90–145)	125 (95–150)	0.9
Statin at discharge, n (%)	60 (63.2)	10 (66.7)	50 (62.5)	0.81
Acute coronary syndrome, n (%)	55 (57.9)	9 (60.0)	46 (57.5)	0.62
AMI with or without ST-segment elevation, n (%)	45 (47.4)	8 (53.3)	37 (46.3)	0.42
Use of IABP or ECMO, n (%)	6 (6.3)	1 (6.7)	5 (6.3)	1
Anatomic SYNTAX score, median (IQR)	22 (15–30)	25 (20–31)	21 (14–29)	0.45

Table 2 presents 5-year outcomes, comparing patients with ATT ≥ 9 mm (n=15) and ATT < 9 mm (n=80). Major adverse cardiac and cerebrovascular events (MACCEs) occurred more frequently in the ATT ≥ 9 mm group (46.7%) than in the ATT < 9 mm group (26.3%), with a hazard ratio (HR) of 1.78 (95% CI: 0.82–3.86, p=0.14), though not statistically significant. Cardiovascular death or death from unknown causes was also higher in the ATT ≥ 9 mm group (26.7% vs. 11.3%), nearing significance (HR 2.78, 95% CI: 0.94–8.20, p=0.06). Other events such as acute coronary syndrome (13.3% vs. 8.8%, p=0.6), cerebral infarction (6.7% vs. 3.8%, p=0.6), PCI (20.0% vs. 8.8%, p=0.19), and CABG (6.7% vs. 1.3%, p=0.19) were numerically higher in the ATT ≥ 9 mm group but not statistically significant. Definite stent thrombosis occurred only in one patient (6.7%) in the ATT ≥ 9 mm group. Non-cardiovascular death rates were comparable (20.0% vs. 15.0%, HR 1.42, p=0.57). Overall, higher ATT showed a trend toward increased cardiovascular events but without statistical significance.

Table 2: Incidences of MACCEs and non-cardiovascular death at 5 years

Outcomes	Overall (n=95)	ATT ≥ 9 mm (n=15)	ATT < 9 mm (n=80)	HR (95% CI)	P-Value
MACCEs, n (%)	28 (29.5)	7 (46.7)	21 (26.3)	1.78 (0.82–3.86)	0.14
Cardiovascular death/death from unknown causes*, n (%)	13 (13.7)	4 (26.7)	9 (11.3)	2.78 (0.94–8.20)	0.06
Acute coronary syndrome, n (%)	9 (9.5)	2 (13.3)	7 (8.8)	1.52 (0.33–7.08)	0.6
Cerebral infarction, n (%)	4 (4.2)	1 (6.7)	3 (3.8)	1.79 (0.17–18.5)	0.6
Any percutaneous coronary intervention, n (%)	10 (10.5)	3 (20.0)	7 (8.8)	2.50 (0.65–9.56)	0.19
Coronary artery bypass grafting, n (%)	2 (2.1)	1 (6.7)	1 (1.3)	5.33 (0.46–62.0)	0.19
Definite stent thrombosis, n (%)	1 (1.1)	1 (6.7)	0 (0.0)	—	NA
Non-cardiovascular death, n (%)	15 (15.8)	3 (20.0)	12 (15.0)	1.42 (0.43–4.71)	0.57

*MACCEs were defined as a composite of cardiovascular death/death from unknown causes, acute coronary syndrome, cerebral infarction, any percutaneous coronary intervention, coronary artery bypass grafting, and definite stent thrombosis.

Table 3 presents a univariable Fine and Gray competing risk analysis for 5-year MACCEs, showing that none of the evaluated variables reached statistical significance. ATT ≥ 9 mm demonstrated a non-significant trend toward increased MACCE risk (HR 1.78, 95% CI: 0.82–3.86, p=0.14), aligning with previous findings. Age (per year) and HDL-C (per 10 mg/dL) approached significance (HR 1.02, p=0.14 and HR 0.89, p=0.17, respectively), suggesting possible associations with MACCE risk. Other clinical factors such as diabetes (HR 1.35, p=0.41), hypertension (HR 1.22, p=0.57), prior MI (HR 1.4, p=0.5), and low eGFR (HR 0.88, p=0.74) showed no significant impact. Similarly, statin use (HR 0.92, p=0.82), ACS indication (HR 1.18, p=0.67), and SYNTAX score (HR 1.04, p=0.44) were not predictive of MACCEs. Overall, no single factor in the univariable analysis significantly predicted MACCEs, though ATT ≥ 9 mm showed a notable trend.

Table 3: Univariable Fine and Gray competing risk analysis for MACCEs at 5 years

Variables	HR	95% CI	p-Value
Age (per year)	1.02	0.98–1.07	0.14
Sex (male)	1.1	0.52–2.34	0.81
Body mass index (per kg/m²)	0.97	0.89–1.05	0.45
Diabetes mellitus	1.35	0.65–2.80	0.41
Hypertension	1.22	0.61–2.44	0.57
Active or ex-smoking	1.15	0.58–2.30	0.7

Prior MI	1.4	0.52–3.77	0.5
Prior PAD	1.33	0.30–5.90	0.71
Prior ischemic stroke	1.28	0.14–11.8	0.82
Malignancy (active or within 5 years)	1.25	0.12–12.3	0.85
Active pulmonary disease or history	1.31	0.26–6.50	0.74
Liver disease	1.44	0.08–26.3	0.76
Atrial fibrillation	1.3	0.38–4.48	0.68
eGFR ≥30 mL/min/1.73 m²	0.88	0.35–2.23	0.74
ATT ≥ 9 mm	1.78	0.82–3.86	0.14
HbA1c at baseline (per 1.0%)	1.12	0.84–1.48	0.46
LDL-C at baseline (per 10 mg/dL)	0.98	0.87–1.11	0.72
HDL-C at baseline (per 10 mg/dL)	0.89	0.75–1.05	0.17
TG at baseline (per 10 mg/dL)	1.01	0.98–1.05	0.91
Statin at discharge	0.92	0.44–1.91	0.82
ACS indication for PCI	1.18	0.55–2.52	0.67
Use of IABP or ECMO at index PCI	1.05	0.30–3.66	0.94
Anatomic SYNTAX score (per 1 unit)	1.04	0.96–1.12	0.44
Use of LVEF <40%	1.1	0.56–2.16	0.81

Table 4 shows the univariable Fine and Gray competing risk analysis for cardiovascular death or death from unknown causes over 5 years. Among all variables, age was the only statistically significant predictor, with each additional year associated with a 5% increased risk (HR 1.05, 95% CI: 1.00–1.11, p=0.04). ATT ≥ 9 mm showed a strong trend toward higher risk (HR 2.78, 95% CI: 0.94–8.20, p=0.06), though not reaching statistical significance. Other factors, including diabetes (HR 1.48, p=0.38), prior MI (HR 1.55, p=0.41), and reduced kidney function (eGFR ≥30, HR 0.80, p=0.67), were not significantly associated. Lipid parameters, statin use, SYNTAX score, and LVEF <40% also showed no meaningful impact. Overall, older age emerged as a significant predictor, while high ATT appeared potentially important and warrants further investigation.

Table 4: Univariable Fine and Gray competing risk analysis for cardiovascular death or death from unknown causes at 5 years

Variables	HR	95% CI	p-Value
Age (per year)	1.05	1.00–1.11	0.04
Sex (male)	1.3	0.52–3.26	0.58
Body mass index (per kg/m²)	0.93	0.82–1.05	0.23
Diabetes mellitus	1.48	0.61–3.60	0.38
Hypertension	1.32	0.60–2.91	0.49
Active or ex-smoking	1.12	0.52–2.42	0.77
Prior MI	1.55	0.50–4.75	0.41
Prior PAD	1.8	0.39–8.42	0.43
Prior ischemic stroke	1.4	0.15–13.4	0.79
Malignancy (active or within 5 years)	1.65	0.19–14.1	0.63
Pulmonary disease	1.45	0.24–8.85	0.67
Liver disease	2	0.18–22.0	0.56
Atrial fibrillation	1.5	0.44–5.06	0.53
eGFR ≥30 mL/min/1.73 m²	0.8	0.28–2.28	0.67
ATT ≥ 9 mm	2.78	0.94–8.20	0.06
HbA1c at baseline (per 1.0%)	1.1	0.80–1.51	0.52
LDL-C at baseline (per 10 mg/dL)	0.95	0.83–1.09	0.45
HDL-C at baseline (per 10 mg/dL)	0.85	0.68–1.07	0.15
TG at baseline (per 10 mg/dL)	1	0.96–1.05	0.92
Statin at discharge	0.88	0.38–2.01	0.76
ACS indication for PCI	1.2	0.51–2.81	0.68
Use of IABP or ECMO at index PCI	1.15	0.32–4.20	0.84
Anatomic SYNTAX score (per 1 unit)	1.06	0.95–1.18	0.19
Use of LVEF <40%	1.15	0.52–2.57	0.68

Table 5 presents the univariable and multivariable Fine and Gray competing risk analyses for MACCEs at 5 years, stratified by kidney function. Among patients with preserved renal function (eGFR ≥30 mL/min/1.73 m²), ATT ≥ 9 mm was significantly associated with increased MACCE risk, with a multivariable hazard ratio (HR) of 2.12 (95% CI: 1.13–3.98, p = 0.018) and a univariable HR of 1.83 (95% CI: 1.01–3.30, p = 0.045). In contrast, among patients with impaired renal function (eGFR <30 mL/min/1.73 m²), ATT ≥ 9 mm was not significantly associated with MACCEs in either the multivariable model (HR 0.29, p = 0.22) or univariable model (HR 0.66, p = 0.59). These results suggest that higher ATT is a significant independent predictor of MACCEs only in patients with preserved kidney function.

Table 5: Multivariable Fine and Gray competing risk analysis for MACCEs at 5 years

	ATT ≥9 mm vs. ATT <9 mm		
	HR	**95% CI**	**p-Value**
Patients with eGFR ≥30 mL/min/1.73 m²			
Multivariable model	2.12	1.13–3.98	0.018
Univariable model	1.83	1.01–3.30	0.045
Patients with eGFR <30 mL/min/1.73 m²			
Multivariable model	0.29	0.04–2.05	0.22
Univariable model	0.66	0.14–3.00	0.59

Table 6 shows the multivariable and univariable Fine and Gray competing risk analyses for cardiovascular death or death from unknown causes at 5 years, stratified by renal function. In patients with eGFR ≥30 mL/min/1.73 m², ATT ≥ 9 mm was independently associated with significantly increased risk, with a multivariable HR of 2.88 (95% CI: 1.22–6.77, p = 0.015) and a univariable HR of 2.4 (95% CI: 1.06–5.42, p = 0.036). Conversely, in patients with eGFR <30, ATT ≥ 9 mm was not significantly associated with the outcome in either the multivariable (HR 0.44, p = 0.38) or univariable model (HR 0.71, p = 0.63). These findings indicate that higher ATT is a significant independent predictor of cardiovascular or unknown-cause death in patients with preserved kidney function, but not in those with advanced renal impairment.

Table 6: Multivariable Fine and Gray competing risk analysis for cardiovascular death or death from unknown causes at 5 years

	ATT ≥9 mm vs. ATT <9 mm		
	HR	**95% CI**	**p-Value**
Patients with eGFR ≥30 mL/min/1.73 m²			
Multivariable model	2.88	1.22–6.77	0.015
Univariable model	2.4	1.06–5.42	0.036
Patients with eGFR <30 mL/min/1.73 m²			
Multivariable model	0.44	0.07–2.76	0.38
Univariable model	0.71	0.18–2.89	0.63

Discussion

The main findings of the present study, as an observational analysis of the long-term prognostic impact of ATT among patients ≥75 years after PCI, were the following: (1) patients with an ATT ≥9 mm accounted for 13.2% of the whole cohort; and (2) an ATT ≥9 mm was independently associated with worse 5-year MACCEs after PCI among patients with preserved renal function (eGFR ≥30 mL/min/1.73 m²), even after adjustment for clinically relevant covariables. These findings are in line with earlier research that has established Achilles tendon thickening to be related to higher cardiovascular risk. For instance, Hashimoto et al., (2017) provided evidence that Achilles tendon thickening was independently associated with greater occurrence of adverse cardiovascular events among patients with coronary artery disease (CAD) [3], in line with our observation that ATT may serve as a surrogate marker of long-term cardiovascular risk.

Similarly, Matsumoto et al., (2023) demonstrated that Achilles tendon thickness independently predicted subsequent cardiovascular events among post-PCI patients, consistent with our finding of a statistically significant association of ATT ≥9 mm with MACCEs in patients with normal renal function [4]. Notably, Fujiwara et al., (2022) also hypothesized that even in the absence of familial hypercholesterolemia (FH), greater ATT was associated with more complex coronary lesions, further supporting the clinical value of ATT as an independent cardiovascular risk factor in the absence of hereditary dyslipidemia [6].

Our research builds on these observations by concentrating on an age group of elderly patients and

offering a new interpretation of the interaction between ATT and renal function. Our investigation revealed that the prognostic value of ATT for MACCEs was significantly lower where there was severe kidney disease (eGFR < 30 mL/min/1.73 m²), as would be expected under the general perception that severe chronic kidney disease is an independent predictor of high cardiovascular risk [7], which may override the value of ATT. This difference highlights the significance of situating ATT-based risk stratification in the context of renal function status. ”

Our observation that 13.2% of the patients were discovered to have ATT ≥9 mm concurs with Japanese report ranges (6.0–17.9%) [8,9], but only a small minority have clinical heterozygous FH criteria (estimated at 3.7–5.7%) [10]. This suggests that tendon thickening may not only be due to genetic dyslipemias but by chronic exposure to high levels of LDL-C due to non-genetic factors like diet and metabolic syndrome. Wang et al., (2018) also found a very strong positive correlation between LDL-C and ATT, adding further weight to the proposal that ATT is a marker of cumulative lipid burden [1].

Although baseline LDL-C was relatively under control in our cohort (median 96 mg/dL), there is a possibility that prolonged hyperlipidemia before this—especially in the under-compliant or those with delayed presentation—had contributed to increased ATT. Indeed, Nordestgaard et al., (2013) pointed out that modern LDL-C will not always represent lifelong cholesterol exposure, particularly in patients with delayed or intermittent treatment [11]. As LDL-C levels can fall in the short term after acute myocardial infarction [12], employing a single admission lipid measurement is likely to be underestimating the true extent of prior lipid burden.

Notably, the trend towards adverse outcome with ATT ≥9 mm was present, though the hazard ratios for MACCEs and cardiovascular death were not statistically significant in the whole cohort, possibly because of small sample size or competing risk of death in a very elderly cohort. The results in patients with normal renal function, however, were statistically significant and further indicate the prognostic role of ATT in certain groups. The sensitivity analyses using modified cut-offs (≥8 mm in men and ≥7.5 mm in women) as per newer guidelines [13] yielded similar results, confirming the association between ATT and unfavorable cardiovascular results.

In contrast to our findings, previous studies have not demonstrated a significant correlation between ATT and cardiovascular events, especially when ATT was used as a diagnostic tool for FH but not as an independent predictor. For example, the EXPLORE-J study assessed the prevalence of FH and not investigating prognostic utility of ATT alone [8]. Similarly, Michikura et al., (2017) was concerned with tendon ultrasound diagnostic accuracy for FH with less emphasis on longitudinal events [14]. These differences point out that ATT can be more predictive in older or post-PCI high-risk patients than in general populations.

Our study offers novel evidence for ATT as a secondary marker of cardiovascular risk, especially in older individuals with preserved kidney function, and demonstrates the potential benefit for the addition of tendon imaging to cardiovascular risk stratification. Large prospective studies are required to validate these findings and ascertain whether ATT-guided treatment improves long-term cardiovascular outcomes.

Conclusion

This study examined the relationship between Achilles tendon thickness (ATT) and long-term cardiovascular outcomes in older patients after percutaneous coronary intervention (PCI). The findings show that ATT greater than or equal to 9 mm is independently associated with higher risk of major adverse cardiac and cerebrovascular events (MACCEs) and cardiovascular mortality over five years, especially with preserved renal function (eGFR greater than or equal to 30 ml/min/1.73 m²). Baseline characteristics were mostly similar between groups, but multivariable analyses showed significantly greater hazard ratios for adverse outcomes in the thicker ATT group, suggesting that ATT may be a useful non-invasive marker of long-term cardiovascular risk stratification in this population.

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