

Feasibility and Diagnostic Validity of Cardiac Magnetic Resonance Imaging in Octogenarians and Nonagenarians: A Retrospective Single-Center Analysis of 1153 Consecutive Patients

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Abstract

Objectives

Cardiovascular disease is highly prevalent in elderly patients, yet data on cardiac magnetic resonance imaging (CMR) feasibility and diagnostic validity in patients aged 80 years and older remain scarce. We aimed to determine the real-world feasibility of CMR in octogenarians and nonagenarians and to identify independent predictors of premature scan termination and limited evaluability.

Methods

This retrospective single-center study included all patients aged ≥ 80 years undergoing CMR (1.5T/3T, Siemens) as part of inpatient treatment at a tertiary cardiology department between February 2014 and November 2021. Primary outcomes were premature scan termination and limited evaluability. Two-independent-samples t-tests and chi-square tests were used for univariable comparisons; binary logistic regression was performed for each outcome to identify independent predictors.

Results

A total of 1153 patients (567 male, 586 female; mean age 82.9 ± 2.9 years, range 80–100) were included. CMR was prematurely terminated in 45 patients (3.9%). Terminated patients were significantly older (84.3 ± 3.5 vs 82.8 ± 2.9 years; $p = 0.001$) and more likely to be undergoing stress perfusion testing (42.2% vs 26.8%; $p = 0.030$). On multivariable analysis, older age was an independent predictor of premature termination (OR 1.13 per year, 95% CI 1.04–1.24; $p = 0.004$). A diagnostically conclusive result was obtained in 1084 examinations (94.0%); 69 scans (6.0%) had limited evaluability. Age and sex were not significantly associated with limited evaluability. However, indication was a strong independent predictor: compared to stress perfusion testing, myocarditis evaluation carried a five-fold higher risk of limited evaluability (OR 5.02, 95% CI 2.42–14.60; $p < 0.001$), and viability assessment a three-fold higher risk (OR 3.08, 95% CI 1.44–9.18; $p = 0.017$). Pre-/post-pulmonary vein isolation imaging had the lowest risk of limited evaluability.

Conclusions

CMR is feasible in the large majority of elderly patients aged 80 years and above. However, older age independently predicts premature scan termination, and scan indication — rather than patient age or sex — is the primary driver of limited evaluability, with myocarditis and viability protocols carrying significantly higher risk. These findings have direct implications for patient counselling, protocol planning, and resource allocation in geriatric CMR practice.

1 Introduction

Population aging is among the most consequential demographic trends of the 21st century. In Europe, individuals aged 65 and older account for approximately one-fifth of the population, a proportion projected to reach 30% by 2070, while the share of those aged 80 and above is expected to at least double by 2070.^[1–4]

This demographic shift carries a major rise in cardiovascular disease burden. Atrial fibrillation (AF), coronary artery disease, and myocardial infarction (MI) are all strongly age-dependent, yet diagnostic assessment in this population is complicated by multimorbidity, polypharmacy, and geriatric syndromes that can confound the interpretation of conventional imaging studies.^[5–7]

Cardiac magnetic resonance imaging (CMR) provides comprehensive assessment of cardiac morphology, function, perfusion, and tissue characterization without ionizing radiation, and is endorsed by current guidelines across multiple cardiovascular indications.^[23] In the very elderly, however, CMR faces specific challenges: prolonged scan times increase susceptibility to motion artifact; the high prevalence of cardiac implantable devices may limit or preclude scanning;^[19, 20] tolerance of the examination is often compromised by dyspnea, claustrophobia, or poor compliance; and normative reference data in patients above 75–80 years of age remain scarce.^[22]

Despite the growing clinical demand for CMR in elderly patients, systematic real-world data on its feasibility across different indications in patients aged 80 and above remain limited, and no large study has used multivariable analysis to identify independent predictors of both premature termination and limited evaluability in this population. The objective of this study was therefore to determine the overall feasibility and diagnostic validity of CMR in octogenarians and nonagenarians in routine clinical practice, and to identify independent predictors of adverse scan outcomes.

2 Methods

2.1 Study design and population

This retrospective, single-center study was conducted at the Department of Cardiology and Angiology, Regiomed Hospital Coburg, Germany. All consecutive patients aged ≥ 80 years who underwent CMR as part of inpatient treatment between 3 February 2014 and 29 November 2021 were eligible for inclusion. CMR was performed on a 3.0T (Verio, Siemens Healthineers, Erlangen, Germany) or 1.5T (Espree, Siemens Healthineers) scanner. Patients younger than 80 years at the time of the scan and those for whom complete records could not be retrieved were excluded. The study was approved by the Institutional Review Board of the Regiomed Medical School (18 March 2022) and conducted in accordance with the Declaration of Helsinki (2013 revision). Individual informed consent was waived by the IRB in view of the retrospective, fully anonymized nature of the data.

2.2 CMR protocols

All examinations began with standard localizer and HASTE sequences, followed by cine imaging in long-axis and short-axis views to assess ventricular function. Protocol-specific sequences were added according to indication: T2-weighted imaging and late gadolinium enhancement (LGE) for acute and chronic viability; adenosine or dobutamine stress perfusion plus rest perfusion and LGE for ischemia; pulmonary vein angiography and three-dimensional left atrial LGE for pre-/post-PVI imaging; and early gadolinium enhancement combined with T2 and LGE for suspected myocarditis. Gadolinium-based contrast (Clariscan, GE Healthcare, 0.3–0.4 mmol/kg intravenously) was administered where indicated.

2.3 Outcomes and definitions

Premature termination was defined as any scan terminated before protocol completion at the patient's request or due to a clinical or technical reason. Limited evaluability was defined as a completed scan that could not be fully interpreted with respect to the clinical question due to insufficient image quality or other factors, as documented by the reporting cardiologist. Reasons for each adverse outcome were extracted from original radiology reports. Indication was classified into five mutually exclusive categories based on recorded protocol flags: stress perfusion testing (adenosine or dobutamine), viability assessment (acute or chronic post-MI), pre-/post-PVI imaging for AF, myocarditis evaluation, and other.

2.4 Statistical analysis

Statistical analysis was performed using Python (version 3.10; scipy v1.9 and scikit-learn v1.8). Continuous normally distributed variables are presented as mean $\pm$ standard deviation; categorical variables as counts and percentages. Differences between groups were assessed using the two-tailed Student's t-test for continuous variables and the Pearson chi-square test for categorical variables. Binary logistic regression was performed separately for each outcome (premature termination; limited evaluability), incorporating age (continuous), sex, and indication category (reference: stress perfusion testing) as covariates. Odds ratios (OR) with 95% bootstrap confidence intervals (2000 resamples, percentile method) and Wald-test p-values are reported. A two-sided P-value < 0.05 was considered statistically significant.

3 Results

3.1 Patient characteristics and indications

A total of 1153 patients (567 male [49.2%], 586 female [50.8%]) were included. Mean age was 82.9 ± 2.9 years (range 80–100); 1118 patients (97%) were aged 80–89 years and 35 (3%) were ≥ 90 years. The leading indications for CMR were stress perfusion testing with adenosine or dobutamine (27.4%; $n = 316$), viability assessment in the acute or chronic setting after MI (26.4%; $n = 304$), imaging before and after PVI for AF (19.5%; $n = 225$), and evaluation for suspected myocarditis (17.7%; $n = 204$). The remaining 9.0% ($n = 104$) were less common indications (Table 1). The distribution of indications is illustrated in Fig. 2. Mean scan duration was 40.8 ± 10.5 minutes (range 5–80 min).

Table 1
Indications for cardiac MRI in the study cohort (n = 1153).

Indication	n	%
Stress testing (adenosine or dobutamine)	316	27.4
Viability assessment, acute or chronic post-MI	304	26.4
Imaging before/after pulmonary vein isolation for AF	225	19.5
Myocarditis assessment	204	17.7
Other (tumor, thrombus, systemic disease)	104	9.0
<i>AF: atrial fibrillation; MI: myocardial infarction; MRI: magnetic resonance imaging; PVI: pulmonary vein isolation.</i>		

Table 1. Indications for cardiac MRI in the study cohort (n = 1153).

3.2 Premature scan termination

Forty-five examinations (3.9%) were terminated prematurely. On univariable analysis, patients who terminated the scan were significantly older (84.3 ± 3.5 vs 82.8 ± 2.9 years; $t = 3.353$, $p = 0.001$) and more likely to be undergoing stress perfusion testing than any other indication (chi-square = 10.679, $p = 0.030$). Sex was not significantly associated with premature termination (60.0% female in terminated vs 50.5% in non-terminated; chi-square = 1.219, $p = 0.270$) (Table 2; Fig. 2).

Table 2
Univariable comparison between patients with and without premature scan termination.

Variable	Terminated (n = 45)	Non-terminated (n = 1108)	p-value
Age, years, mean $\pm$ SD	84.3 ± 3.5	82.8 ± 2.9	0.001
Female sex, n (%)	27 (60.0)	559 (50.5)	0.270
Indication, n (%)			0.030
Stress testing	19 (42.2)	297 (26.8)	
Viability assessment	6 (13.3)	298 (26.9)	
Pre-/post-PVI for AF	5 (11.1)	220 (19.9)	
Myocarditis evaluation	8 (17.8)	196 (17.7)	
Other	7 (15.6)	97 (8.8)	
<i>Data are mean $\pm$ SD or n (%). P-values from independent-samples t-test (continuous) and chi-square test (categorical). AF: atrial fibrillation; PVI: pulmonary vein isolation; SD: standard deviation.</i>			

The most frequent reasons for termination were the patient's own wish without a further specified clinical cause (62.2%, n = 28), unspecified reason (15.6%, n = 7), and angina pectoris (6.7%, n = 3).

Claustrophobia, dyspnea, and non-compliance each accounted for 4.4% (n = 2) (Table 5).

Table 5
Reasons for premature termination of cardiac MRI
(n = 45).

Reason	n	%
Patient's wish	28	62.2
Not specified	7	15.6
Angina pectoris	3	6.7
Dyspnea	2	4.4
Non-compliance	2	4.4
Claustrophobia	2	4.4
Technical problem	1	2.2
Comorbidities	1	2.2
Error in image reconstruction	1	2.2
Contraindication for MRI detected	1	2.2
Multiple artifacts	1	2.2

On multivariable logistic regression, older age was the only independent predictor of premature termination (OR 1.13 per year, 95% CI 1.04–1.24; $p = 0.004$). Indication category and sex were not independently significant in the multivariable model (Table 4; Fig. 1A). The age distributions of terminated and non-terminated patients are shown in Fig. 3A.

Table 4

Multivariable binary logistic regression: independent predictors of premature scan termination and limited evaluability.

Variable	Premature termination OR (95% CI)	p	Limited evaluability OR (95% CI)	p
Age (per year)	1.13 (1.04–1.24)	0.004	1.00 (0.92–1.08)	0.935
Female sex	1.49 (0.82–3.00)	0.225	0.74 (0.43–1.26)	0.275
Viability vs Stress	0.35 (0.08–0.84)	0.073	3.08 (1.44–9.18)	0.017
PVI vs Stress	0.46 (0.09–1.14)	0.224	0.52 (0.00–1.91)	0.829
Myocarditis vs Stress	0.81 (0.32–1.72)	0.613	5.02 (2.42–14.60)	< 0.001
Other vs Stress	1.21 (0.36–2.75)	0.714	3.53 (1.22–10.82)	0.024
<i>OR = odds ratio; CI = 95% bootstrap confidence interval (2000 resamples). Reference category for indication: stress perfusion testing. P-values from Wald test. AF: atrial fibrillation; PVI: pulmonary vein isolation.</i>				

Table 2. Univariable comparison between patients with and without premature scan termination.

3.3 Diagnostic evaluability

Of the 1153 examinations, 1084 (94.0%) yielded a result fully evaluable with respect to the clinical question. Limited evaluability was documented in 69 scans (6.0%). On univariable analysis, age (83.1 ± 2.9 vs 82.9 ± 2.9 years; $t = 0.705$, $p = 0.481$) and sex (42.0% female in limited vs 51.4% in full evaluability; chi-square = 1.913, $p = 0.167$) were not significantly associated with limited evaluability (Fig. 3B). In contrast, indication category was a highly significant predictor (chi-square = 31.101, $p < 0.001$): myocarditis scans (36.2% of limited evaluability group vs 16.5% of full evaluability group) and viability scans (33.3% vs 25.9%) were markedly overrepresented, while PVI imaging was substantially underrepresented (4.3% vs 20.5%) among scans with limited evaluability (Table 3; Fig. 2).

Table 3
Univariable comparison between patients with and without limited evaluability.

Variable	Limited evaluability (n = 69)	Full evaluability (n = 1084)	p-value
Age, years, mean $\pm$ SD	83.1 $\pm$ 2.9	82.9 $\pm$ 2.9	0.481
Female sex, n (%)	29 (42.0)	557 (51.4)	0.167
Indication, n (%)			< 0.001
Stress testing	9 (13.0)	307 (28.3)	
Viability assessment	23 (33.3)	281 (25.9)	
Pre-/post-PVI for AF	3 (4.3)	222 (20.5)	
Myocarditis evaluation	25 (36.2)	179 (16.5)	
Other	9 (13.0)	95 (8.8)	
<i>Data are mean $\pm$ SD or n (%). P-values from independent-samples t-test (continuous) and chi-square test (categorical). AF: atrial fibrillation; PVI: pulmonary vein isolation; SD: standard deviation.</i>			

The most common causes of limited evaluability were patient non-compliance (52.9%, n = 36), an unspecified or undocumented cause (26.5%, n = 18), arrhythmia (22.1%, n = 15), and the presence of cardiac implants (16.2%, n = 11) (Table 6).

Table 6
Reasons for limited evaluability of cardiac MRI
(n = 69).

Reason	n	%
Non-compliance	36	52.9
Not clearly specified	18	26.5
Arrhythmia	15	22.1
Cardiac implants	11	16.2
Artifacts (motion or other)	4	5.9
Dyspnea	4	5.9
Pleural/pericardial effusion	3	4.4
Poor image quality (general)	3	4.4
Area of interest not visible	1	1.5
Decompensated heart failure	1	1.5
<i>MRI: magnetic resonance imaging.</i>		

On multivariable logistic regression, age and sex were not independently associated with limited evaluability. Compared with stress perfusion testing (reference category), myocarditis evaluation (OR 5.02, 95% CI 2.42–14.60; $p < 0.001$) and viability assessment (OR 3.08, 95% CI 1.44–9.18; $p = 0.017$) were independently associated with significantly higher odds of limited evaluability. PVI imaging was associated with lower odds, although this was not statistically significant (OR 0.52, 95% CI 0.00–1.91; $p = 0.829$) (Table 4; Fig. 1B).

Table 3. Univariable comparison between patients with and without limited evaluability.

Table 4. Multivariable logistic regression: independent predictors of premature termination and limited evaluability.

4 Discussion

In this large single-center cohort of 1153 consecutive patients aged 80–100 years undergoing CMR in routine clinical practice, we demonstrate three key findings. First, CMR is broadly feasible in this population, with premature termination in fewer than 4% and full diagnostic evaluability in 94.0% of examinations. Second, older age within this already very elderly cohort independently predicts premature scan termination, with each additional year of age conferring approximately 13% higher odds. Third, and perhaps most clinically actionable, scan indication — not patient age or sex — is the dominant independent predictor of limited evaluability: myocarditis and viability protocols carry a five-fold and three-fold higher risk of limited evaluability respectively compared with stress perfusion testing, while PVI imaging is remarkably reliable.

The overall feasibility of CMR in our cohort is consistent with earlier, smaller studies. Esteban-Fernández *et al.* demonstrated that stress CMR was safe and prognostically informative in patients over 70 years, [34] and Forman *et al.* identified implants, prolonged scan times, and renal function as major barriers to CMR in older adults. [22] Our data extend these observations to a substantially older and larger population, and critically move beyond overall feasibility rates to provide indication-specific, multivariable-adjusted risk estimates that can directly inform clinical decision-making.

The finding that older age independently predicts premature termination — even within a cohort already restricted to patients aged 80 and above — has practical implications. Clinicians should anticipate higher scan termination risk in patients approaching 85–90 years and consider pre-procedural counselling, dedicated patient preparation, and potentially shorter or modular CMR protocols for the oldest patients. The prominence of stress perfusion testing among terminated scans (42.2% vs 26.8% in non-terminated) likely reflects the longer duration and pharmacological stress burden of these protocols, which may be less tolerable in very elderly patients.

The indication-specific risk pattern for limited evaluability is a novel and clinically important finding. The very high risk associated with myocarditis protocols (OR 5.02) plausibly reflects the need for high-quality T2 and early gadolinium enhancement sequences, which are particularly sensitive to cardiac motion and

respiratory artifacts — problems more pronounced in older patients with arrhythmias, reduced breath-hold capacity, and orthopnea. The higher risk of limited evaluability for viability scans (OR 3.08) may similarly reflect the complex multi-sequence protocol required. In contrast, the remarkably low rate of limited evaluability for PVI imaging likely reflects the shorter standardized protocol and the fact that left atrial anatomy imaging is less susceptible to motion degradation than functional or tissue characterization sequences. These findings should prompt dedicated protocol optimization efforts for myocarditis and viability imaging in elderly patients — for example, use of free-breathing or navigator sequences, reduced breath-hold durations, and arrhythmia-robust pulse sequences.

The indication distribution in our cohort — led by stress perfusion testing and viability assessment — differs from the broader EuroCMR registry, in which CAD risk stratification was the leading indication.^[35] This divergence likely reflects both the restriction to patients aged ≥ 80 years in our cohort and local referral patterns, and reinforces the value of population-specific feasibility data.

4.1 Study limitations

Several limitations should be considered. First, this is a retrospective single-center study; while the large consecutive sample and long study period strengthen the findings, prospective multicenter data would allow more definitive estimates. Second, image quality was assessed via original clinical reports rather than by independent blinded re-review, which may introduce reporting variability. Third, the logistic regression models used bootstrap confidence intervals derived from a Python implementation rather than a dedicated statistical package; while this approach is valid, results should be confirmed with validated software (e.g., SPSS or R) before definitive publication. Fourth, scanner field strength (1.5T vs 3T) was not included as a covariate due to incomplete per-patient documentation, but may have influenced evaluability in some cases.

5 Conclusions

CMR is feasible and diagnostically useful in the large majority of patients aged 80 years and older. Older age within this cohort independently predicts premature scan termination, while scan indication — not age or sex — is the primary independent determinant of limited evaluability. Myocarditis and viability protocols carry significantly higher risk of limited evaluability compared to stress perfusion imaging, whereas pre-/post-PVI imaging is highly reliable even in very elderly patients. These findings provide practical guidance for patient selection, pre-procedural counselling, and protocol optimization in geriatric CMR practice.

Abbreviations

AF = atrial fibrillation; CMR = cardiac magnetic resonance imaging; CI = confidence interval; LGE = late gadolinium enhancement; MI = myocardial infarction; OR = odds ratio; PVI = pulmonary vein isolation; SD = standard deviation

Declarations

Conflicts of interest: The authors declare no conflicts of interest.

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Author Contributions

I.A.: conceptualization, formal analysis, writing – original draft, writing – review and editing, corresponding author. L.R.H.: data curation, data collection. T.M.: data curation, clinical data validation. C.M.: supervision, writing – review and editing, project administration. All authors read and approved the final manuscript.

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Figures

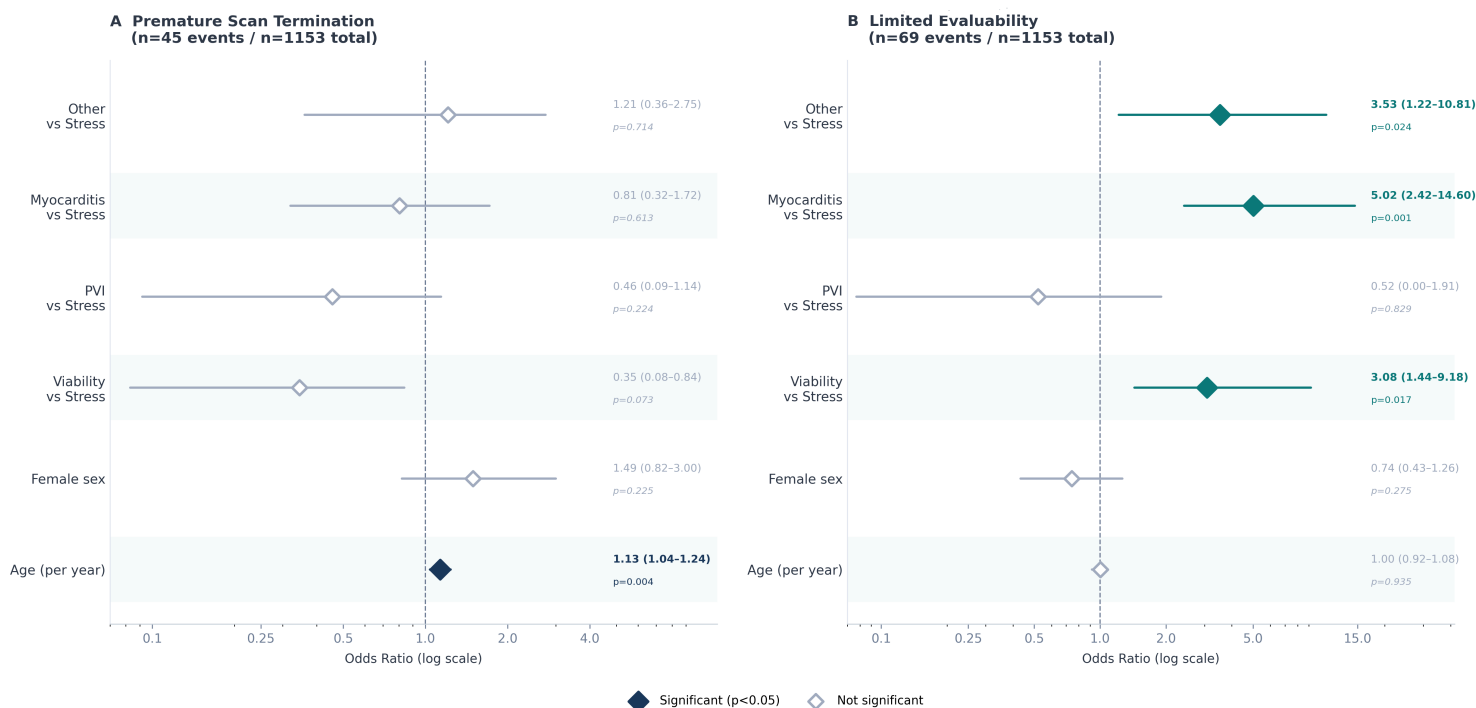


Figure 1

Multivariable binary logistic regression: independent predictors of premature scan termination (panel A) and limited evaluability (panel B) in 1153 patients aged ≥80 years undergoing cardiac MRI. Filled diamond markers indicate statistically significant predictors (p < 0.05); open markers indicate non-significant associations. Reference category for indication: stress perfusion testing. OR: odds ratio; CI: 95% bootstrap confidence interval; PVI: pulmonary vein isolation.



Figure 2

Rates of premature scan termination and limited evaluability by CMR indication in the study cohort. Bars represent the proportion of patients within each indication group experiencing each adverse outcome. Asterisks denote indications with significantly higher limited evaluability vs stress perfusion testing in multivariable analysis. OR: odds ratio; PVI: pulmonary vein isolation; AF: atrial fibrillation.

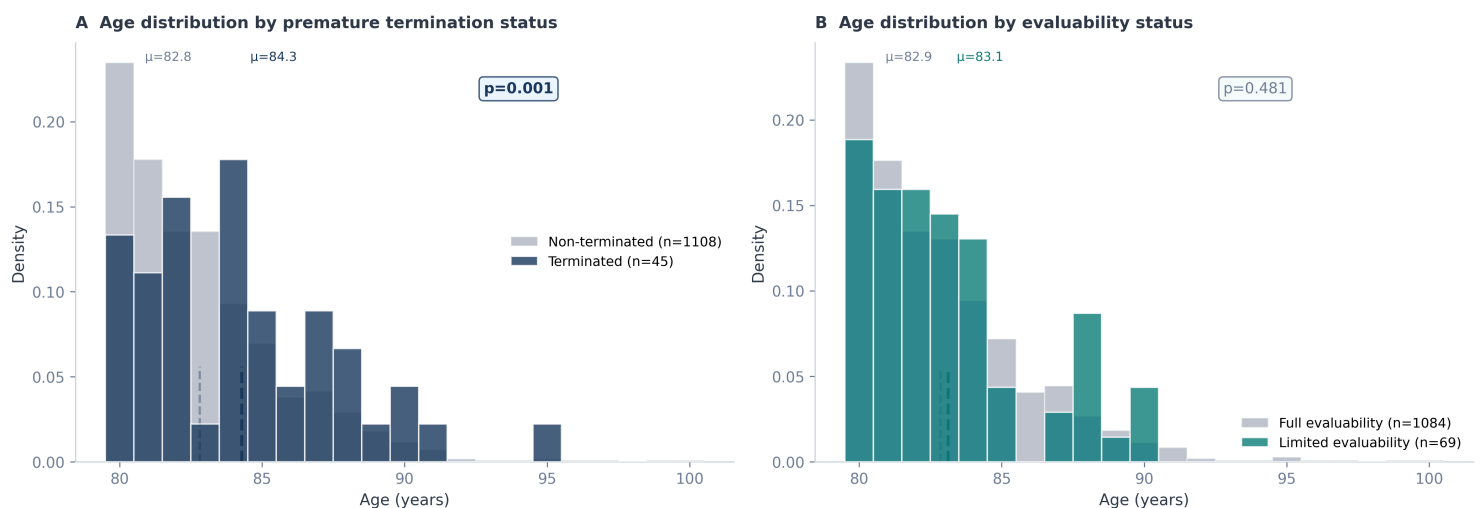


Figure 3

Age distributions in patients with and without premature scan termination (panel A) and with and without limited evaluability (panel B). Dashed vertical lines indicate group means. P-values from independent-samples t-test.

