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Prevalence and Natural Course of Radiographic C1-2 Osteoarthritis: A CT-based analysis of health-checkup participants

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Abstract

Purpose: Radiographic C1-2 osteoarthritis (OA) may be detected in populations not selected for neck symptoms, but longitudinal data are limited. We evaluated its prevalence, natural course, and associated factors.Methods: This retrospective cohort study included 689 health-checkup participants with paired whole-body computed tomography examinations at least 5 years apart. C1-2 OA was graded from 0 to 3. Baseline OA was defined as grade 1 or higher, incident OA as progression from grade 0 to grade 1 or higher, and worsening as an increase of at least one grade among participants with baseline grade 1 or 2. Logistic regression was used to identify associated factors.Results: Baseline OA was present in 102 participants (14.8%). Incident OA occurred in 6 of 587 participants (1.0%), and worsening occurred in 22 of 96 participants (22.9%). Baseline OA was independently associated with older age (odds ratio [OR] 1.07, 95% confidence interval [CI] 1.04–1.10), diffuse idiopathic skeletal hyperostosis (OR 1.98, 95% CI 1.11–3.53), a history of spine surgery (OR 15.52, 95% CI 3.19–75.61), and higher hemoglobin A1c (OR 1.68, 95% CI 1.17–2.40). In an exploratory model, higher inorganic phosphorus was associated with worsening (OR 8.47, 95% CI 2.10–34.20).Conclusion: Radiographic C1-2 OA was present in 14.8% of participants and worsened in 22.9% of those with pre-existing grade 1 or 2 OA. Radiographic C1-2 OA should not be equated with symptomatic disease.

Introduction

C1-2 osteoarthritis (C1-2 OA) is a degenerative disorder of the upper cervical spine and is a recognized cause of posterior neck pain and restricted cervical rotation [1]. Because the atlantoaxial joint accounts for a large proportion of cervical rotation [2], degeneration at this level can have clinical consequences that differ from those of subaxial cervical degeneration.

Previous studies have linked C1-2 OA to aging and mechanical loading. Zapletal et al. reported that the prevalence of advanced C1-2 OA increased with age [3]. Badve et al. found frequent occipito-atlanto-axial degenerative changes in individuals exposed to repetitive head loading [4].

Systemic metabolic factors may also be relevant. Diabetes has been associated with severe OA in a longitudinal cohort study and with OA in a meta-analysis [5, 6]. Diffuse idiopathic skeletal hyperostosis (DISH) is also associated with aging, obesity, diabetes, and other metabolic abnormalities [7, 8]. Mechanical loading at C1-2 may also change when motion of the subaxial spine is reduced. Conditions that reduce subaxial mobility, such as DISH-related ankylosis or subaxial spinal fusion, may therefore increase stress at the remaining mobile upper cervical segments [7–9]. These findings suggest that radiographic C1-2 OA may be related to both local mechanical factors and systemic metabolic factors.

Several surgical series have reported favorable pain relief after C1-2 fusion for carefully selected patients with intractable atlantoaxial OA [10, 11]. These results indicate the importance of accurate diagnosis. However, radiographic degeneration alone does not establish symptomatic disease. Determining the frequency and natural course of radiographic C1-2 OA in a health-checkup population not selected for

neck symptoms is therefore clinically important when interpreting computed tomography (CT) findings in patients with neck pain.

Using a longitudinal health-checkup cohort, this study aimed to determine the prevalence and natural course of radiographic C1-2 OA and to identify characteristics associated with baseline radiographic C1-2 OA and worsening of pre-existing C1-2 OA.

Materials and Methods

We hypothesized that radiographic C1-2 OA would be associated with demographic, metabolic, and spine-related factors and that pre-existing OA would show radiographic worsening during follow-up.

Study population

This was a retrospective cohort study of participants in a health-checkup program. Between 2016 and 2023, the health-checkup database contained 13,669 examination records, including repeated visits by the same individuals. Because the longitudinal analysis required two health-checkup visits separated by at least 5 years, records from individuals with only one visit or a follow-up period of less than 5 years were excluded. For each remaining participant, only the first and final health-checkup records were retained, yielding 1,396 records from 698 individuals. After excluding four individuals who declined CT imaging and five with rheumatoid arthritis, 689 participants with paired baseline and follow-up CT images were included in the final cohort.

Participants underwent CT as part of a health-checkup program and were not referred for neck symptoms. The study flow is shown in Fig. 1.

Numbers before pairing indicate examination records, whereas numbers after pairing indicate individuals.

CT, computed tomography.

The study size was based on eligible participants with baseline and follow-up CT images. The mean follow-up period was 2,060 ± 167 days.

In the main analyses, we performed a cross-sectional analysis using the presence of baseline radiographic C1-2 OA as the dependent variable and a longitudinal analysis evaluating worsening of pre-existing radiographic C1-2 OA during follow-up. The definitions of the outcomes are described below.

This study was approved by our Institutional Ethics Committee (No. R4019). At the time of participation in the health-checkup program, participants provided written consent for secondary research use of their clinical and imaging data. The present retrospective study included only individuals who had provided such consent. All procedures were conducted in accordance with the Declaration of Helsinki. This study

was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

Radiographic assessment

Whole-body CT images were obtained as part of the institutional health-checkup program using a Biograph mCT Flow64-4R scanner (Siemens Healthineers, Erlangen, Germany), as previously described [12]. Repeat whole-body CT examinations were performed as part of routine serial health checkups, independently of the present study and irrespective of neck symptoms. No CT examination was obtained specifically for research purposes. The scan range extended from the apex of the skull to the middle of the thighs. The acquisition parameters included a matrix size of 512 × 512, field of view of 500 × 500 mm, and slice thickness of 2.0 mm. C1-2 OA was assessed using axial images and multiplanar reconstructed coronal and sagittal images (Aquarius NET, TeraRecon Co.) of the upper cervical spine.

C1-2 OA severity was graded using a four-point scale adapted from the CT classification of lateral atlantoaxial joint degeneration described by Lakshmanan et al. [13]: grade 0, no apparent osteoarthritic change; grade 1, mild osteoarthritic change, such as osteophyte formation, without definite joint-space narrowing or articular surface contact; grade 2, moderate OA with joint-space narrowing; and grade 3, severe OA with articular surface contact (Fig. 2).

Figure 2 Representative CT images of C1-2 OA grades.

Coronal and sagittal CT images showing representative examples of grade 0 to grade 3 C1-2 OA. CT, computed tomography; C1-2 OA, C1-2 osteoarthritis

Both left and right C1-2 joints were evaluated, and the higher grade was used as the participant-level C1-2 OA grade. All baseline and final CT images were directly reviewed and graded by a board-certified orthopedic surgeon.

Interobserver and intraobserver reliability were assessed before the final analysis using baseline and final CT images from a stratified subset of 30 participants, yielding 60 CT examinations. For interobserver reliability, a second board-certified orthopedic surgeon independently evaluated the images while blinded to the primary assessment and clinical data. For intraobserver reliability, the second assessor repeated grading after a washout interval. Linear weighted kappa statistics were calculated for the four-grade C1-2 OA scale, and Cohen's kappa statistics were calculated for binary radiographic C1-2 OA and DISH. Imaging assessment was performed independently of medical record information and without reference to baseline demographics, laboratory data, or DISH status.

DISH was evaluated according to the previously reported CT-based early-phase DISH criteria [14]. Briefly, intervertebral spaces were scored as 0, no new bone formation; 1, newly formed bone extending across the intervertebral space but without bridging; 2, near-complete bridging with ≤ 2 mm of separation between both sides; or 3, complete bridging. DISH was defined as either at least one segment with

complete bridging and an adjacent segment with near-complete bridging plus another adjacent segment with newly formed bone, or at least three adjacent segments with near-complete bridging. Among participants with DISH, the most cranial involved region of DISH was recorded descriptively as cervical, thoracic, or lumbar.

Outcomes

The primary outcome in the cross-sectional analysis was baseline radiographic C1-2 OA, defined as grade 1 or higher on the four-point severity scale. The longitudinal outcome was worsening of pre-existing radiographic C1-2 OA, and worsening was defined as an increase of at least one grade from baseline to final assessment. Participants with baseline grade 3 were excluded from this analysis because grade 3 represented the highest severity category and further grade progression could not be defined. Incident radiographic C1-2 OA was defined as transition from baseline grade 0 to grade 1 or higher and was summarized descriptively.

For cross-sectional analyses, the four-grade scale was dichotomized as grade 0 versus grade 1 or higher to evaluate the presence of any radiographic C1-2 OA. For longitudinal analyses, the original four-grade scale was retained to describe grade transitions, whereas regression analyses modeled worsening versus no worsening because individual transition categories were sparse.

Candidate explanatory variables included age, sex, body mass index (BMI), bone mineral density assessed by dual-energy X-ray absorptiometry (DXA), calcium, albumin, inorganic phosphorus, C-reactive protein (CRP), high-sensitivity CRP, triglycerides, glycated albumin, hemoglobin A1c (HbA1c), free thyroxine, diabetes mellitus, smoking status, alcohol consumption, history of spine surgery, DISH, and tartrate-resistant acid phosphatase 5b (TRACP-5b).

Statistical analysis

All statistical analyses were performed using R software, version 4.6.0 (R Foundation for Statistical Computing, Vienna, Austria) [15]. Continuous variables are presented as means with standard deviations, and categorical variables are presented as numbers with percentages. For comparisons between participants with and without baseline radiographic C1-2 OA, Welch’s t-test was used for continuous variables, and the chi-square test or Fisher’s exact test was used for categorical variables, as appropriate.

Univariable logistic regression analyses were performed for each candidate explanatory variable. Multivariable logistic regression analyses were then conducted using variables selected on the basis of clinical relevance, univariable results, and the number of outcome events. Variables with $p < 0.10$ in univariable analyses were considered for inclusion, but the final models were restricted to avoid overfitting. The variables included in each final multivariable model are shown in the corresponding tables.

For the longitudinal analysis, the main multivariable model included age, HbA1c, and baseline C1-2 OA grade. Baseline grade was included as an adjustment variable because the number of possible grade transitions differed between baseline grade 1 and grade 2. Because the number of worsening events was limited, the number of explanatory variables was restricted to avoid overfitting. A separate exploratory model including age, inorganic phosphorus, and baseline C1-2 OA grade was also constructed.

Continuous variables were analyzed per unit increase, except for TRACP-5b, which was analyzed per 100-unit increase to improve interpretability. Complete-case analysis was performed for each model using only participants without missing data for the dependent and explanatory variables. Therefore, the number of participants included in the analysis differed among models.

Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated from logistic regression models. A p value < 0.05 was considered statistically significant. Reliability coefficients were interpreted using conventional categories of agreement.

Results

Study population

The study flow is shown in Fig. 1. A total of 689 participants were included in the final study cohort, and the mean follow-up period was 2,060 ± 167 days.

Baseline characteristics

The prevalence of baseline radiographic C1-2 OA, defined as grade 1 or higher, was 14.8% (102/689). The mean age of the overall cohort was 58.9 ± 9.7 years. Baseline characteristics are summarized in Table 1.

Table 1
Baseline characteristics according to baseline radiographic C1-2 OA status

Variable	Overall (n = 689)	Without C1-2 OA (n = 587)	With C1-2 OA (n = 102)	*p* value
Demographic and clinical characteristics				
Age (years)	58.92 ± 9.68	57.83 ± 9.40	65.21 ± 8.88	< 0.001
Sex, male	419 (60.8%)	353 (60.1%)	66 (64.7%)	0.446
BMI (kg/m²)	24.14 ± 4.26	23.98 ± 4.19	24.59 ± 4.45	0.232
Smoking, yes	241 (62.0%)	175 (61.0%)	66 (64.7%)	0.584
Alcohol use, yes	200 (51.4%)	144 (50.2%)	56 (54.9%)	0.481
History of spine surgery, yes	14 (3.6%)	2 (0.7%)	12 (11.8%)	< 0.001
Diabetes mellitus, yes	80 (20.6%)	50 (17.4%)	30 (29.4%)	0.015
Radiographic findings				
DISH, yes	148 (21.5%)	110 (18.7%)	38 (37.3%)	< 0.001
Cranial extent of DISH, cervical	51 (34.5%)	36 (32.7%)	15 (39.5%)	
Cranial extent of DISH, thoracic	97 (65.5%)	74 (67.3%)	23 (60.5%)	
Bone mineral density				
BMD by DXA (g/cm²)	2.55 ± 0.31	2.56 ± 0.31	2.50 ± 0.32	0.096
Laboratory data				
HbA1c (%)	5.80 ± 0.65	5.75 ± 0.60	6.03 ± 0.86	0.002
Glycated albumin (%)	13.96 ± 2.02	13.86 ± 1.88	14.52 ± 2.64	0.018
Calcium (mg/dL)	9.13 ± 0.31	9.13 ± 0.31	9.11 ± 0.31	0.463
Inorganic phosphorus (mg/dL)	3.40 ± 0.43	3.41 ± 0.42	3.32 ± 0.43	0.056
TRACP-5b (mU/dL)	344.40 ± 136.65	339.49 ± 135.01	372.60 ± 143.13	0.031
Albumin (g/dL)	4.19 ± 0.25	4.19 ± 0.24	4.14 ± 0.28	0.068
CRP (mg/dL)	0.15 ± 0.26	0.15 ± 0.23	0.18 ± 0.37	0.496

Variable	Overall (n = 689)	Without C1-2 OA (n = 587)	With C1-2 OA (n = 102)	*p* value
Demographic and clinical characteristics				
High-sensitivity CRP (mg/L)	0.07 ± 0.10	0.07 ± 0.10	0.08 ± 0.10	0.498
Triglycerides (mg/dL)	124.11 ± 122.92	124.10 ± 127.33	124.17 ± 94.24	0.995
FT4 (ng/dL)	1.29 ± 0.20	1.29 ± 0.21	1.31 ± 0.17	0.330

Table 1. **Baseline characteristics according to baseline radiographic C1-2 OA status**

Values are presented as mean ± standard deviation or number (%). Percentages were calculated using the number of participants with available data for each variable as the denominator. Percentages for the cranial extent of DISH were calculated among participants with DISH. No participant had a lumbar cranial extent; therefore, only cervical and thoracic categories are shown. *p* values were calculated by comparing participants with and without baseline radiographic C1-2 OA. C1-2 OA, C1-2 osteoarthritis; BMI, body mass index; DISH, diffuse idiopathic skeletal hyperostosis; BMD, bone mineral density; DXA, dual-energy X-ray absorptiometry; HbA1c, hemoglobin A1c; TRACP-5b, tartrate-resistant acid phosphatase 5b; CRP, C-reactive protein; FT4, free thyroxine.

Participants with baseline radiographic C1-2 OA were older than those without baseline radiographic C1-2 OA (65.2 ± 8.9 vs 57.8 ± 9.4 years, $p < 0.001$). Baseline radiographic C1-2 OA was more frequent in participants with DISH and in those with a history of spine surgery. The baseline radiographic C1-2 OA group also had higher HbA1c and glycated albumin levels.

The grade transition matrix is shown in Table 2.

Table 2
Transition in C1-2 OA grade from baseline to final CT assessment

Baseline grade	Final grade 0	Final grade 1	Final grade 2	Final grade 3	Total	Progression
Grade 0	581	5	1	0	587	6/587 (1.0%)
Grade 1	0	42	16	1	59	17/59 (28.8%)
Grade 2	0	0	32	5	37	5/37 (13.5%)
Grade 3	0	0	0	6	6	Not applicable
Total	**581**	**47**	**49**	**12**	**689**	**—**

Values are presented as number of participants unless otherwise indicated. C1-2 OA severity was graded as grade 0, none; grade 1, mild; grade 2, moderate; and grade 3, severe. Incident radiographic C1-2 OA was defined as transition from baseline grade 0 to grade 1 or higher. Worsening of pre-existing non-end-stage C1-2 OA was defined as grade progression among participants with baseline grade 1 or grade 2. Participants with baseline grade 3 were not considered at risk for further grade progression because grade 3 was the highest severity category. CT, computed tomography; C1-2 OA, C1-2 osteoarthritis.

Incident radiographic C1-2 OA, defined as transition from baseline grade 0 to grade 1 or higher, occurred in 6 of 587 participants with baseline grade 0 (1.0%). Among the 102 participants with baseline radiographic C1-2 OA, 96 had pre-existing non-end-stage C1-2 OA, defined as grade 1 or grade 2. Worsening of pre-existing non-end-stage C1-2 OA occurred in 22 of 96 participants (22.9%).

Interobserver and intraobserver reliability were almost perfect for the four-grade C1-2 OA scale, with linear weighted kappa values of 0.903 and 0.917, respectively. For binary radiographic C1-2 OA, kappa values were 0.902 and 0.949, respectively. For DISH, kappa values were 0.933 and 1.000, respectively.

Factors associated with baseline C1-2 OA

The results of the univariable and multivariable analyses are shown in Table 3.

Table 3
Logistic regression analyses for factors associated with baseline radiographic C1-2 OA

Variable	Univariable analysis		Multivariable analysis	
	OR (95% CI)	***p* value**	**OR (95% CI)**	***p* value**
Demographic and clinical characteristics				
Age (years)	1.09 (1.06–1.11)	< 0.001	1.07 (1.04–1.10)	< 0.001
Sex, male	1.22 (0.79–1.90)	0.383		
BMI (kg/m²)	1.03 (0.98–1.09)	0.220		
Smoking, yes	1.17 (0.74–1.89)	0.505		
Alcohol use, yes	1.21 (0.77–1.91)	0.412		
History of spine surgery, yes	19.00 (5.06–123.58)	< 0.001	15.52 (3.19–75.61)	< 0.001
Diabetes mellitus, yes	1.97 (1.16–3.32)	0.011		
Radiographic findings				
DISH, yes	2.57 (1.63–4.03)	< 0.001	1.98 (1.11–3.53)	0.021
Bone mineral density				
BMD by DXA (g/cm²)	0.54 (0.26–1.07)	0.082		
Laboratory data				
HbA1c (%)	1.68 (1.27–2.22)	< 0.001	1.68 (1.17–2.40)	0.005
Glycated albumin (%)	1.14 (1.04–1.25)	0.004		
Calcium (mg/dL)	0.77 (0.39–1.53)	0.460		
Inorganic phosphorus (mg/dL)	0.61 (0.37–1.00)	0.051		
TRACP-5b, per 100 mU/dL	1.18 (1.02–1.36)	0.025	1.16 (0.96–1.40)	0.136
Albumin (g/dL)	0.42 (0.18–0.98)	0.043	0.82 (0.28–2.39)	0.717
CRP (mg/dL)	1.35 (0.62–2.56)	0.365		
High-sensitivity CRP (mg/L)	1.90 (0.24–11.80)	0.514		
Triglycerides (mg/dL)	1.00 (1.00–1.00)	0.996		
FT4 (ng/dL)	1.51 (0.54–3.85)	0.395		

Table 3. **Logistic regression analyses for factors associated with baseline radiographic C1-2 OA**

Values are presented as odds ratios with 95% confidence intervals. Univariable and multivariable logistic regression analyses were performed with baseline radiographic C1-2 OA, defined as grade 1 or higher, as the dependent variable. The final multivariable model included age, DISH, history of spine surgery, HbA1c, albumin, and TRACP-5b. Blank cells in the multivariable columns indicate variables not included in the final multivariable model. TRACP-5b was analyzed per 100-unit increase. C1-2 OA, C1-2 osteoarthritis; BMI, body mass index; DISH, diffuse idiopathic skeletal hyperostosis; BMD, bone mineral density; DXA, dual-energy X-ray absorptiometry; HbA1c, hemoglobin A1c; TRACP-5b, tartrate-resistant acid phosphatase 5b; CRP, C-reactive protein; FT4, free thyroxine.

In univariable analysis, older age, DISH, a history of spine surgery, higher HbA1c levels, higher glycated albumin, diabetes mellitus, higher TRACP-5b, and lower albumin were associated with baseline radiographic C1–2 OA. In multivariable analysis, older age (OR 1.07, 95% CI 1.04–1.10, $p < 0.001$), DISH (OR 1.98, 95% CI 1.11–3.53, $p = 0.021$), a history of spine surgery (OR 15.52, 95% CI 3.19–75.61, $p < 0.001$), and higher HbA1c levels (OR 1.68, 95% CI 1.17–2.40, $p = 0.005$) remained independently associated with baseline radiographic C1–2 OA. Albumin and TRACP-5b were not independently associated after adjustment.

Factors associated with worsening of pre-existing C1-2 OA

The results of the longitudinal analyses are shown in Table 4.

Table 4
Multivariable logistic regression analyses for worsening of pre-existing non-end-stage radiographic C1-2 OA

Variable	Main model		Exploratory model	
	Adjusted OR (95% CI)	*p* value	Adjusted OR (95% CI)	*p* value
Age (years)	1.03 (0.97–1.09)	0.336	1.03 (0.97–1.10)	0.300
HbA1c (%)	1.14 (0.68–1.91)	0.608	—	—
Inorganic phosphorus (mg/dL)	—	—	8.47 (2.10–34.20)	0.003
Baseline grade 2 vs grade 1	0.35 (0.11–1.08)	0.067	0.19 (0.05–0.71)	0.013

Values are presented as adjusted odds ratios with 95% confidence intervals. The analysis included participants with baseline grade 1 or grade 2 C1-2 OA (n = 96; 22 events). The main model included age, HbA1c, and baseline C1-2 OA grade. The exploratory model included age, inorganic phosphorus, and baseline C1-2 OA grade. Baseline grade was included as an adjustment variable because the number of possible grade transitions differed between baseline grade 1 and grade 2. OR, odds ratio; CI, confidence interval; HbA1c, hemoglobin A1c; C1-2 OA, C1-2 osteoarthritis.

Among participants with pre-existing non-end-stage radiographic C1-2 OA, worsening occurred in 22 of 96 participants (22.9%). Age and HbA1c were not independently associated with worsening after adjustment for baseline grade. In the exploratory model focused on mineral metabolism, higher inorganic phosphorus was associated with worsening of pre-existing C1-2 OA (OR 8.47, 95% CI 2.10–34.20, p = 0.003).

Discussion

In this longitudinal health-checkup cohort, radiographic C1-2 OA was found in 14.8% of participants not selected for neck symptoms. During a mean follow-up of approximately 5.6 years, worsening occurred in 22.9% of participants with pre-existing non-end-stage C1-2 OA. These findings show that radiographic C1-2 OA is not rare even in health-checkup participants.

Older age, DISH, higher HbA1c, and a history of spine surgery were independently associated with baseline radiographic C1-2 OA. Age is a consistent factor in previous reports [3, 13]. Degenerative change at the atlantoaxial joint is therefore likely to be part of age-related upper cervical degeneration, but the present results also show that age alone does not explain C1-2 OA.

The principal contribution of this study is the serial CT-based characterization of incident radiographic OA and worsening of pre-existing OA. Incident radiographic C1-2 OA was uncommon among participants with grade 0 at baseline (1.0%), whereas worsening occurred in 22.9% of those with pre-existing grade 1 or 2 OA. This difference is descriptive, as the baseline groups were not directly compared in an adjusted model.

DISH was independently associated with baseline radiographic C1-2 OA. DISH is a systemic ossifying condition related to aging and metabolic abnormalities [7, 8]. The mechanism underlying its association with radiographic C1-2 OA could not be determined in this study. DISH has also been associated with other degenerative conditions, including lumbar spondylosis and knee OA, in a population-based cohort [16].

A history of spine surgery was associated with baseline radiographic C1-2 OA, but this finding should be interpreted cautiously because few participants had previous spine surgery and the confidence interval was wide. Because information on the surgical region, procedure, and fusion range was unavailable, the association cannot be attributed to adjacent segment disease.

Higher HbA1c was associated with baseline radiographic C1-2 OA, consistent with previous evidence linking diabetes mellitus and OA [5, 6]. In the longitudinal model, no statistically significant association between HbA1c and worsening of pre-existing OA was detected after adjustment for age and baseline grade.

In the exploratory longitudinal model, higher inorganic phosphorus was associated with worsening of pre-existing non-end-stage C1-2 OA. Serum phosphorus has previously been associated with OA

prevalence [17]. The present finding should be interpreted cautiously because the analysis was exploratory and the number of worsening events was limited.

The main clinical implication of this study is the need for diagnostic caution. C1-2 fusion can provide good pain relief in carefully selected patients with intractable symptoms from atlantoaxial OA [10, 11]. However, our cohort shows that radiographic C1-2 OA can be present in participants not selected for neck symptoms at a substantial frequency. Imaging findings should therefore be interpreted together with pain distribution, restriction of cervical rotation, physical findings, and, when needed, diagnostic blocks. Radiographic degeneration alone is not sufficient to diagnose symptomatic C1-2 OA.

This study has several strengths. It evaluated both the prevalence and progression of C1-2 OA using serial CT images from a health-checkup cohort. It also assessed DISH using CT images. These features allowed evaluation of radiographic C1-2 OA in individuals not selected for neck symptoms.

This study has several limitations. First, the retrospective observational design leaves open the possibility of unmeasured confounding. Second, although reliability was evaluated in a subset of images, mild radiographic changes can be difficult to distinguish from no change, and misclassification may still have occurred. Third, clinical data, including posterior neck pain, cervical range of motion, physical examination findings, and quality-of-life measures, were unavailable. Therefore, radiographic worsening should not be interpreted as symptomatic or functional deterioration. Fourth, inclusion in the longitudinal cohort required repeated health checkups with paired CT examinations separated by at least 5 years. Participants who returned for serial health checkups may therefore have differed from those who underwent only a single examination or did not complete long-term follow-up. Complete-case analyses may also have introduced bias related to missing covariate data. Fifth, the whole-body CT protocol was not optimized for detailed evaluation of the cervical spine. The relatively large field of view and 2.0-mm slice thickness may have reduced sensitivity for subtle degenerative changes and may have led to underestimation of mild or incident radiographic C1-2 OA. Sixth, the number of worsening events and the number of participants with a history of spine surgery were small, resulting in imprecise estimates and limiting the number of covariates included in the multivariable models. Seventh, details of previous spine surgery, including the surgical level, procedure, and fusion range, were unavailable. Therefore, the observed association with a history of spine surgery cannot be attributed to adjacent segment disease. Finally, degenerative changes in the subaxial cervical spine were not systematically assessed, and we could not determine whether C1-2 OA represented a focal upper cervical process or part of generalized cervical degeneration.

Conclusions

Radiographic C1-2 OA was present in 14.8% of health-checkup participants, and worsening occurred in 22.9% of those with pre-existing grade 1 or 2 OA. Older age, DISH, higher HbA1c, and a history of spine surgery were associated with baseline radiographic C1-2 OA. Because clinical symptoms and function

were not assessed, these radiographic findings should be interpreted in conjunction with clinical findings, including neck pain and cervical range of motion.

Declarations

Author Contribution

Conceptualization: R.S. and T.Sh. Data curation and investigation: R.S., T.N., and M.Sa. Formal analysis, methodology, and visualization: T.Sh. and R.S. Resources: M.Y. and R.N. Supervision: T.Sh. and S.M. Writing – original draft: R.S. Writing – review and editing: R.S., T.Sh., T.N., M.Sa., T.So., K.M., M.Y., R.N., S.M., and B.O. All authors reviewed and approved the final manuscript.

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Figures

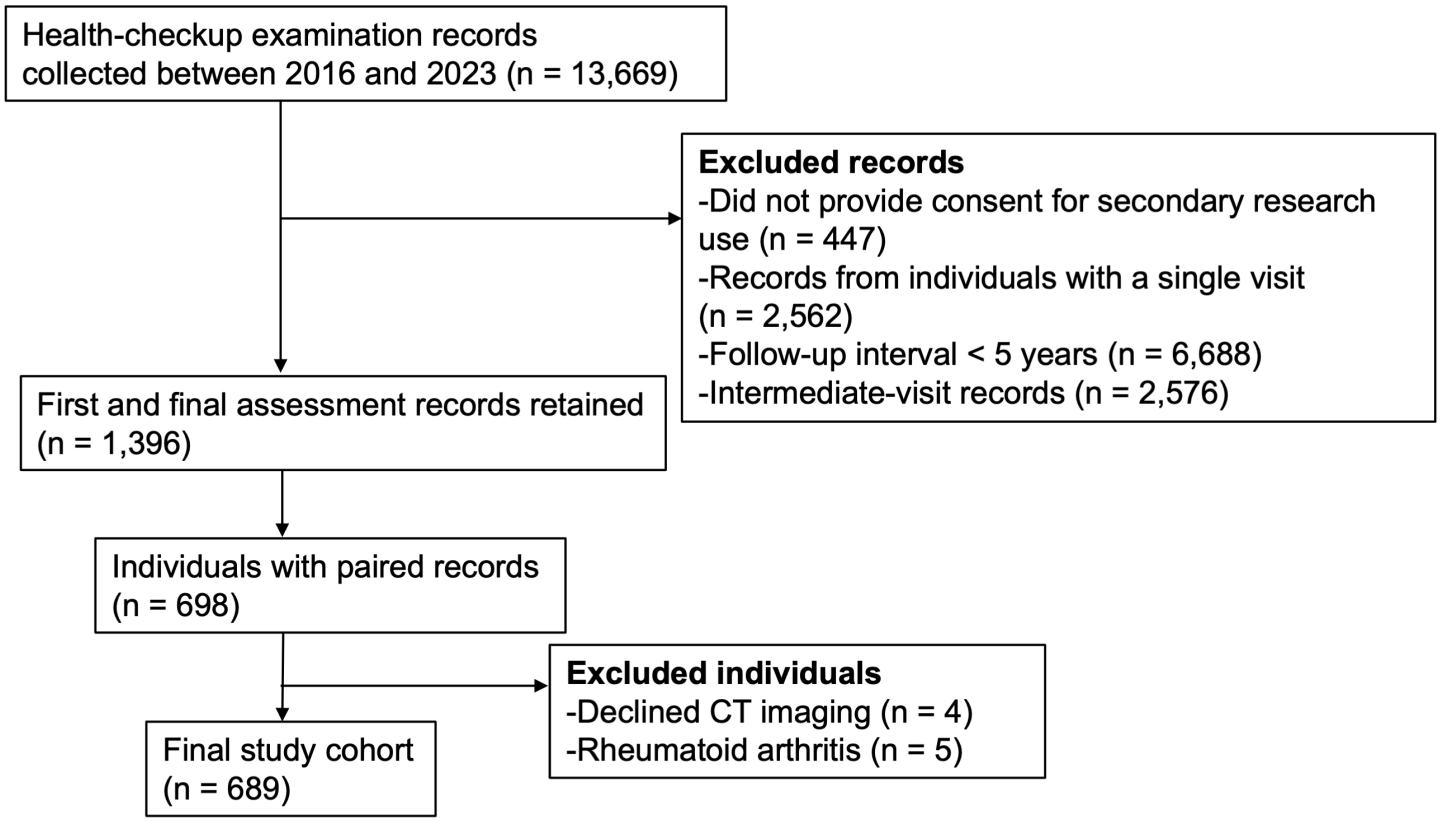


Figure 1

Flowchart of participant selection.

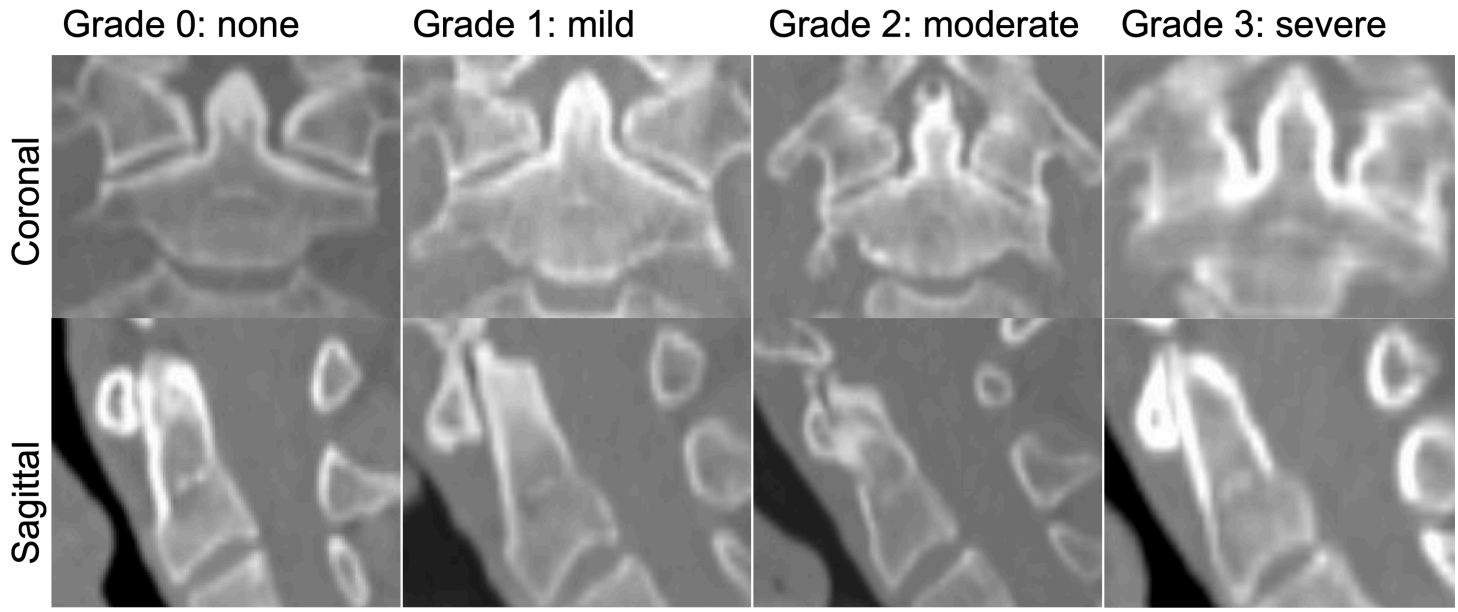


Figure 2

Representative CT images of C1-2 OA grades.