

# Fleischner recommendations for the management of subsolid pulmonary nodules: high awareness but limited conformance – a survey study

Onno M. Mets<sup>1</sup> · Pim A. de Jong<sup>1</sup> · Kaman Chung<sup>2</sup> · Jan-Willem J. Lammers<sup>3</sup> · Bram van Ginneken<sup>2</sup> · Cornelia M. Schaefer-Prokop<sup>2,4</sup>

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## Abstract

**Objectives** The aim of this study was to assess awareness and conformance to the Fleischner society recommendations for the management of subsolid pulmonary nodules (SSN) in clinical practice.

**Methods** An online questionnaire with four imaging cases was sent to 1579 associates from the European Respiratory Society and 757 from the European Society of Thoracic Imaging. Each respondent was asked to choose from several options which one they thought was the indicated management for the nodule presented. Awareness and conformance to the Fleischner recommendations (FR) were assessed and correlated to respondents characteristics.

**Results** In total, 119 radiologists (response rate 16.0 %) and 243 pulmonologists (response rate 16.5 %) were included. Awareness of the FR was higher in radiologists than in pulmonologists (93 % vs. 70 %,  $p < 0.001$ ), as was implementation in daily practice (66 % vs. 47 %,  $p < 0.001$ ). Radiologists conformed to FR in rates of 31, 69, 68, and

82 %, and pulmonologists in 12, 43, 70, and 75 % for cases 1 to 4, respectively. Overmanagement was common. Conformance in SSN management was associated with awareness, working in an academic practice, larger practice size, teaching residents, and higher SSN exposure.

**Conclusions** Although awareness of the Fleischner recommendations for SSN management is widespread, management choices in clinical practice show large heterogeneity.

## Key points

- Guideline awareness among clinicians is widespread, but conformance shows large heterogeneity.
- Awareness and conformance is significantly higher among radiologists than pulmonologists.
- Overmanagement is common, which may lead to avoidable financial and physical burden.

**Keywords** Solitary pulmonary nodule · Adenocarcinoma · Questionnaires · Guideline adherence · Evidence based practice

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✉ Onno M. Mets  
o.m.mets@umcutrecht.nl

- <sup>1</sup> Department of Radiology, University Medical Center Utrecht, Utrecht, The Netherlands
- <sup>2</sup> Diagnostic Imaging Analysis Group, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
- <sup>3</sup> Department of Pulmonology, University Medical Center Utrecht, Utrecht, The Netherlands
- <sup>4</sup> Department of Radiology, Meander Medical Center, Amersfoort, The Netherlands

## Abbreviations

SSN Subsolid nodule  
FR Fleischner recommendations (for the management of subsolid pulmonary nodules)

## Introduction

Pulmonary nodules represent one of the most frequent incidental findings. Subsolid pulmonary nodules (SSNs) form a distinct subgroup of lung nodules, with different morphology and clinical behaviour. Apart from density, the most striking differences are the higher malignancy rate [1] and slower growth rate [2] compared to solid pulmonary nodules. These

characteristics lead to an excellent prognosis when treated early [3–5], however, they also pose the risk of overdiagnosis and overtreatment [6, 7]. A growing understanding of the meaning of the SSN entity and its stepwise progression in the adenomatous spectrum has considerably increased SSN awareness over the last several years. Subsequently, both radiologists and clinicians are increasingly confronted with the dilemma of choosing the most adequate interpretation and management.

In 2013 the Fleischner Society published recommendations for the management of SSNs in daily practice, based on careful review of the available scientific evidence and expert opinion [8]. The need for such a directive is apparent from the fact that the report is listed in the online top ten most-viewed articles in *RADIOLOGY* [9]. Such a fundamental document may help to align management in clinical practice, increase health care quality, and decrease unnecessary procedures. However, to achieve this, it is important that both radiologists and pulmonologists are not only familiar with the Fleischner recommendations (FR), but moreover, act accordingly. Two years after publication it is unknown to which degree the FR are known and indeed applied in daily practice. Therefore, the purpose of this study was to assess awareness and quantify conformance to FR among radiologists and pulmonologists in daily practice.

## Materials and methods

Approval by the institutional ethical review board of the University Medical Center Utrecht, was waived due to the study design.

### Respondents

An invitation to complete an online questionnaire was sent out through the European Society of Thoracic Imaging (ESTI) and the European Respiratory Society (ERS). The ESTI society sent a mailing to 757 unique recipients that were either ESTI members or had visited the annual ESTI conference of 2014. The ERS selected 1579 unique subjects in five relevant scientific groups (i.e. imaging, interventional pulmonology, diffuse parenchymal disease, lung cancer, and pleural and mediastinal malignancies). The survey was open for 4 weeks. A reminder was sent 1 week before closure.

### Online survey

The questionnaire presented four cases with either a new or a persistent pulmonary nodule. Each case was presented with short clinical information on sex, age, and nodule persistency. The nodules were displayed using both a single-axial

computed tomography (CT) slice centred at the lesion, as well as an animated figure that automatically and repeatedly scrolled through the abnormality, providing the full volumetric information in an axial projection. CT images had been acquired using a low-dose protocol (120 or 140 kV at 30 mAs) with a smooth reconstruction kernel (C- or B-filter, Philips Healthcare, Best, The Netherlands). Diameters of the total lesion and the solid component (in mm) were determined manually in the transverse plane using the lung setting (L-600, W1600). Case 1 showed a persistent, pure ground-glass SSN (15x14 mm), case 2 presented a new part-solid SSN with a small solid component (total lesion size 20x16 mm, solid component size 3x4 mm), case 3 showed a persistent part-solid SSN with a large solid component (total lesion size 25x25 mm, solid component size 12x8 mm), and case 4 was a solid triangular nodule with perifissural location near a vein (10x5 mm), illustrating the typical morphology of a benign intrapulmonary lymph node [10]. Figure 1 presents all four imaging cases. The animated figures can be found in the [online supplement](#).

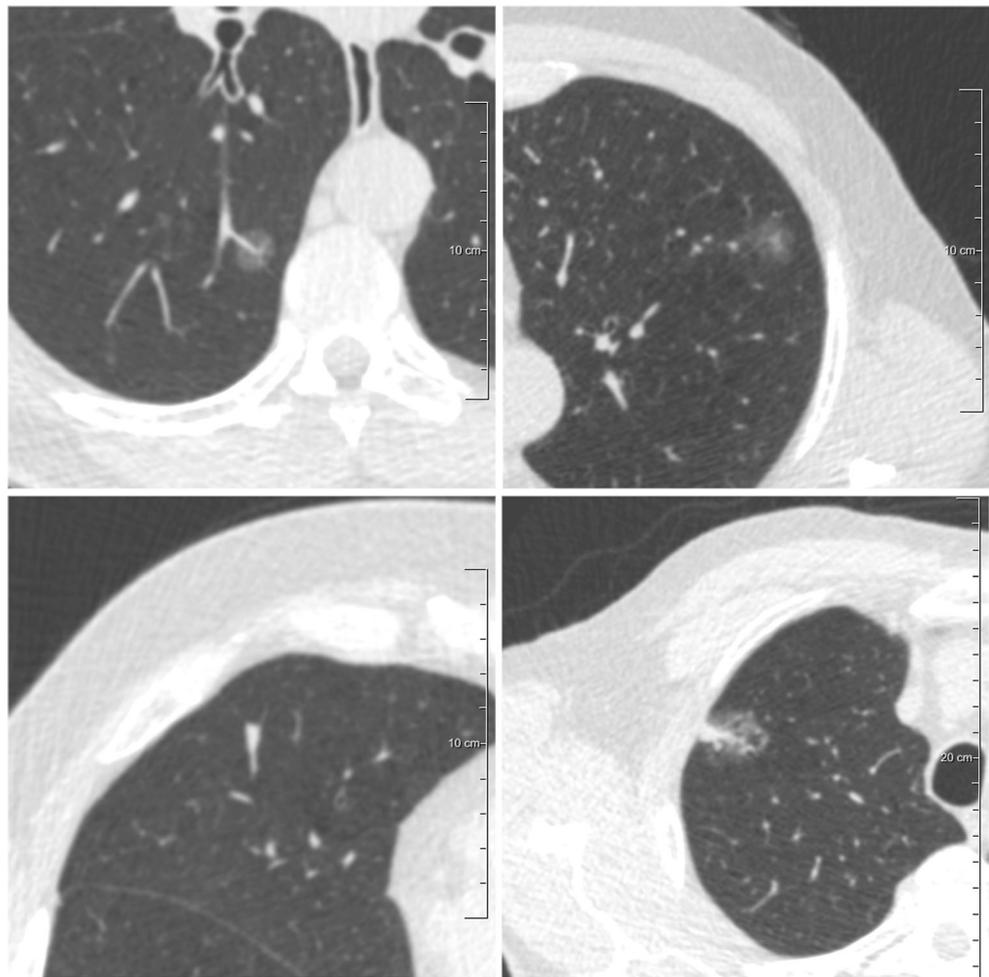
First, the recipients were asked whether they thought the presented nodule concerned a subsolid nodule, and if so, to select what they thought was best medical practise from several management options: (a) nothing; (b) 4-week follow-up; (c) 3-month follow-up; (d) 6-month follow-up; (e) 24-month follow-up; (f) serial follow-up in 12, 24, and 36 months; (g) additional diagnostics (PET-CT, biopsy, etc.); (h) resection of (an almost) certain malignancy; or (i) other. Respondents were limited to providing a single best answer.

Apart from the four imaging cases, the questionnaire also contained a variety of questions focussed on the background and experience of the respondent (e.g. years of experience, type of hospital, practice size). Regarding this information, two slightly different questionnaires were designed for radiologists and pulmonologists. Both questionnaires can be found in the [online supplement](#).

### Analysis

For each case presented, the best management option according to the FR was determined in consensus by three of the authors (OMM, PAJ, and CSP, with 5, >10, and >20 years of experience in thoracic radiology, respectively). This was used as the reference standard. According to the FR the persistent pure SSN in case 1 required serial follow-up at 12, 24, and 36 months. The newly detected part-solid SSN in case 2 required a 3-month follow-up to evaluate persistence. The persistent part-solid SSN in case 3 should be considered a malignancy and required additional action (either resection or PET-CT/biopsy; both answers were considered conform the FR), while the perifissural nodule (PFN) in case 4

**Fig. 1** Imaging cases used in the questionnaire. Clockwise from the upper-left panel, the figure shows a persistent pure ground-glass nodule (case 1), a new part-solid lesion with a small solid component (case 2), a persistent part-solid lesion with larger solid component (case 3), and a triangular solid nodule (case 4)



did not require any follow-up, and in fact did not represent the type of nodule to which the Fleischner recommendations for SSN management apply.

Respondents' answers were compared to the abovementioned reference standard, and recommended management was divided into three categories: (1) conforms to the FR, (2) undermanagement (defined as failure to obtain follow-up at all, failure to obtain the recommended follow-up in time, or failure to perform resection/PET/biopsy in a highly suspicious lesion), or (3) overmanagement (defined as shorter/more frequent follow-up than recommended, or use of additional imaging modalities/invasive techniques considered not indicated). The respondents' management choices were evaluated in relation to their clinical background and experience.

Statistical analyses were performed using SPSS v20.0 for Windows (SPSS, Chicago, Illinois, USA). Comparison between groups (proportions) were performed using chi-squared testing or the Fischer exact test, as appropriate. A *p*-value below 0.05 was considered to represent a significant difference.

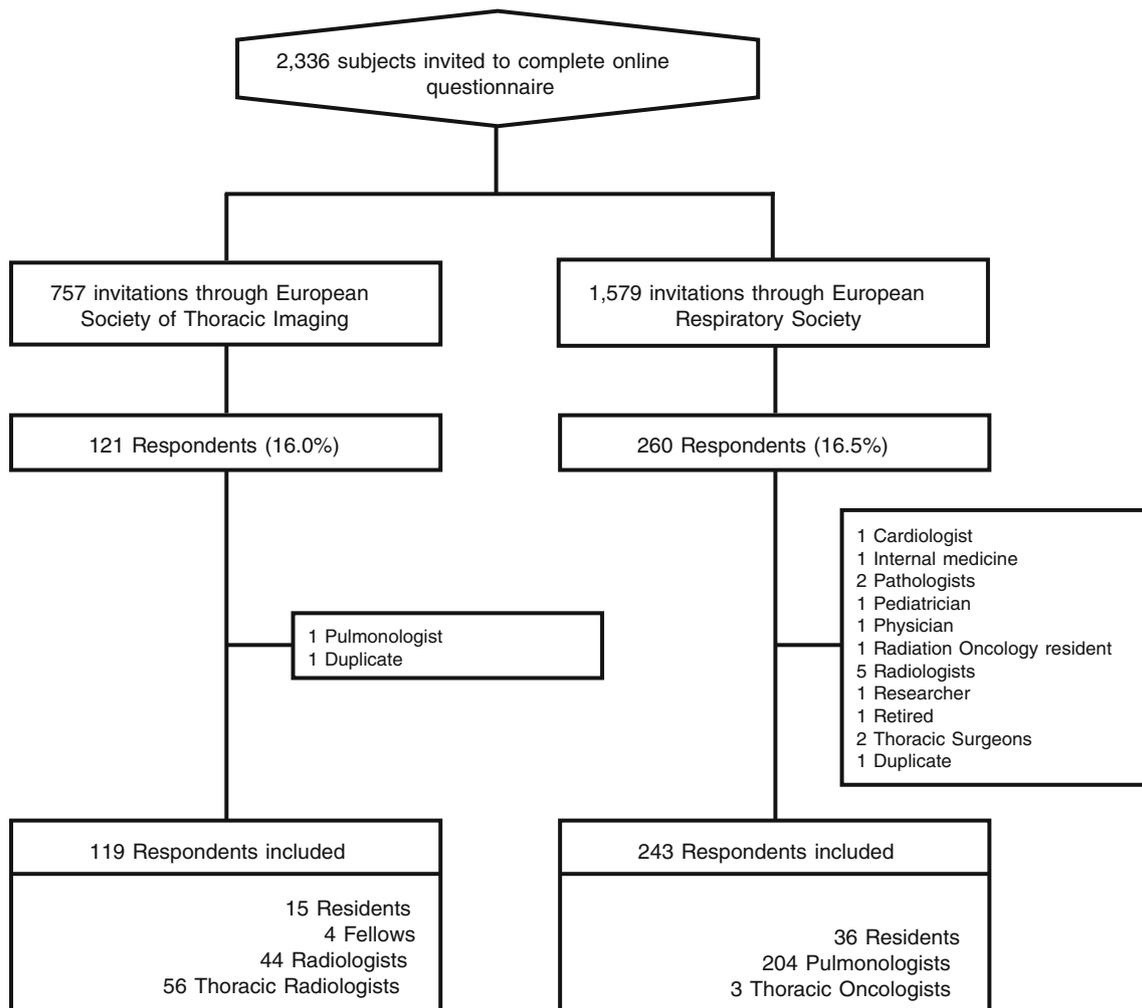
## Results

### Respondents

In total, 121 completed questionnaires were received through ESTI, as were 260 through ERS (response rate 16.0 % and 16.5 %, respectively). Seventeen respondents were excluded due to other job descriptions or incorrect completion of the questionnaire (five radiologists filled in the pulmonology survey and one pulmonologist filled in the radiology survey). Also, two duplicate respondents were excluded. This yielded a total of 362 completed questionnaires by respondents originating from 60 countries (255 European (71 %), five missing). Figure 2 shows the flow chart of the respondent inclusion procedure. Table 1 shows the demographic data of the included respondents.

### Awareness and application in daily practice

Radiologists reported being aware of the Fleischner recommendation for SSN management in 93 % of the



**Fig. 2** Flow chart of respondent inclusion

responses, compared to 70 % of the pulmonologists ( $p < 0.001$ ). Radiologists reported to apply them in daily practice at a rate of 66 % (78/119), while 17 % (20/119) used a locally developed protocol and 10 % (12/119) reported no consistent way of handling SSNs. Only a small proportion of radiologists (3 %, 5/119) did not (or only did so in a minority of cases) include recommendations for nodule management in their report. Overall, 94 % of the radiologists reported moderate to above-average confidence in SSN management (111/119). Pulmonologists adhered to the FR at a rate of 47 % (113/243), while 26 % used a locally developed protocol (62/243), and 18 % reported no consistent way of handling SSNs (43/243). In the case of a recommendation in the report, 47 % (115/243) replied to follow this advice most of the times/always, while 10 % (24/243) ignored it most of the times. Only 38 % (92/243) of the pulmonologists experienced moderate to above-average confidence in managing SSNs ( $p < 0.001$  compared to radiologists).

### Nodule classification and management recommendations

Tables 2 and 3 outline the chosen management strategies per case, showing that when radiologists rated the nodule as an SSN they recommended a strategy conforming to the FR in 31, 69, and 69 % of responses for cases 1 to 3, respectively. The corresponding percentages for pulmonologists were 12, 43, and 70 %, respectively. Radiologists misclassified the lesions in 13, 18, and 13 % of cases, while pulmonologists were incorrect 8, 23, and 26 % of the time in cases 1 to 3, respectively. The solid perifissural nodule was called an SSN by 4 % (5/119) of the radiologists and 14 % (33/243) of the pulmonologists.

For the four presented nodules, overmanagement was chosen in 18–58 % of the cases by radiologists and 25–83 % by pulmonologists. This happened most in the small, pure ground-glass nodule (case 1). The persistent subsolid lesion with a solid component exceeding 5 mm (case 3) triggered an undermanagement in 33 and 54 % of the radiologists and pulmonologists, respectively.

**Table 1** Demographics of included respondents

ESTI respondents (N = 119)		ERS respondents (N = 243)	
Job Title		Job Title	
Radiology resident	15 (13 %)	Pulmonology resident	36 (15 %)
(Cardio) thoracic fellow	4 (3 %)	Pulmonologist	204 (84 %)
Radiologist	44 (37 %)	Thoracic oncologists	3 (1 %)
Thoracic radiologist	56 (47 %)		
Years of experience		Years of experience	
<5 years	21 (18 %)	<5 years	68 (28 %)
5 to 9 years	23 (19 %)	5 to 9 years	43 (18 %)
10 to 19 years	46 (39 %)	10 to 19 years	63 (26 %)
20 years or more	29 (24 %)	20 years or more	69 (28 %)
Type of hospital		Type of hospital	
University/Academic	67 (56 %)	University/Academic	155 (64 %)
General	43 (36 %)	General	55 (23 %)
Private clinic	5 (4 %)	Private clinic	19 (8 %)
Specialized care	4 (3 %)	Specialized care	14 (6 %)
Teaching residents		Teaching residents	
Yes	102 (86 %)	Yes	182 (76 %)
No	17 (14 %)	No	61 (25 %)
No. of chest CT reports p/wk		No. of chest CT reports p/wk	
0	2 (2 %)	N/A	
1 to 49	74 (62 %)	N/A	
50 to 99	30 (25 %)	N/A	
100 or more	13 (11 %)	N/A	
No. of SSN encountered p/yr		No. of SSN encountered p/yr	
1 or less	4 (3 %)	1 or less	15 (6 %)
2 to 10	16 (13 %)	2 to 10	98 (40 %)
11 to 20	30 (25 %)	11 to 20	54 (22 %)
21 or more	69 (58 %)	21 or more	76 (31 %)

ESTI European Society of Thoracic Imaging; ERS European Respiratory Society; SSN Subsolid nodule

Radiologists showed conformance in zero to all four cases in 5, 15, 36, 28, and 16 % of responses, respectively. For pulmonologists this was 7, 31, 46, 15, and 2 %, respectively.

### Correlation between respondents' characteristics and their awareness and conformance

As shown in Table 4, significantly higher awareness was seen in more experienced radiologists ( $\geq 5$  year experience), and in radiologists and pulmonologists with more SSN exposure ( $>10$  SSNs p/year). Awareness of the FR among the different categories of respondents is shown fully in Supplemental Table S1.

On a per-case basis, higher rates of conformance were seen in all four cases for those who were aware of the FR, worked in a larger practice ( $\geq 10$  specialists), and encountered more SSNs ( $>10$  p/year). However, differences did not reach significance in all cases. Awareness among pulmonologists also led

to higher conformance in all cases, but conformance was more variable. Overall analysis showed that highly conformant radiologists (defined as: three or all four cases conform to the FR) were significantly more often aware of the FR ( $p < 0.01$ ), worked in an academic centre ( $p < 0.01$ ), taught residents more often ( $p = 0.02$ ), worked in a practise with  $\geq 10$  specialists ( $p < 0.01$ ), and encountered  $>10$  SSNs p/year ( $p < 0.01$ ). High conformance in pulmonologists was only associated with FR awareness ( $p = 0.02$ ) and  $\geq 10$  year experience ( $p = 0.02$ ). Figure 3 graphically summarises the above-mentioned results.

### Measurement of nodule dimensions

A minority of radiologists indicated that they obtained measurements using volumetric software (8 %, 9/119). Of the radiologists using calipers, only 9 % (10/110) reported obtaining the average of two maximal

**Table 2** Chosen management strategies per case by radiologists or radiology residents

	Case 1		Case 2		Case 3		Case 4	
	SSN	No SSN	SSN	No SSN	SSN	No SSN	SSN	No SSN
Management strategy	103 *	16	97 *	22	105 *	14	5	114 *
Nothing	-	9 (56 %)	-	8 (36 %)	1 (1 %)	3	-	<b>93 (82%)</b> +
4-week FU	1 (1 %)	1 (11 %)	12 (12 %)	4 (18 %)	4 (4 %)	1	1 (20 %)	3 (3 %)
3-month FU	34 (33 %)	1 (11 %)	<b>67 (69%)</b> +	8 (36 %)	20 (19 %)	4	1 (20 %)	3 (3 %)
6-month FU	10 (10 %)	2 (22 %)	2 (2 %)	1 (5 %)	1 (1 %)	1	-	8 (7 %)
24-month FU	5 (5 %)	-	1 (1 %)	-	2 (2 %)	1	1 (20 %)	3 (3 %)
12, 24, and 36-month FU	<b>32 (31%)</b> +	2 (22 %)	4 (4 %)	1 (5 %)	2 (2 %)	-	1 (20 %)	3 (3 %)
Other modality	12 (12 %)	1 (11 %)	4 (4 %)	-	<b>38 (36%)</b> +	1	1 (20 %)	1 (1 %)
Resection	1 (1 %)	-	3 (3 %)	-	<b>34 (32%)</b> +	2	-	-
Other	8 (8 %) <sup>a</sup>	-	4 (4 %) <sup>b</sup>	-	3 (3 %) <sup>c</sup>	1	-	-
Overmanagement	60 (58 %)	N/A	26 (27 %)	N/A	-	N/A	N/A	21 (18 %)
Undermanagement	6 (6 %)	N/A	4 (4 %)	N/A	33 (31 %)	N/A	N/A	-

Case 1 represents a persistent, pure ground-glass SSN (15 × 14 mm); case 2 shows a new part-solid SSN with a small solid component (total lesion size 20 × 16 mm, solid component size 3 × 4 mm); case 3 shows a persistent part-solid SSN with a large solid component (total lesion size 25 × 25 mm, solid component size 12 × 8 mm); and case 4 presents a triangular solid nodule at a perifissural location (10x5 mm)

FU = follow-up; \* = correct characterization of the pulmonary nodule; + = correct management strategy according to Fleischner recommendations for SSN management; <sup>a</sup> = three respondents did not provide management choice; <sup>b</sup> = two respondents did not provide management choice; <sup>c</sup> = one respondent did not provide management choice

diameters in the axial plane, as described in the Fleischner document. Only 13 % (28/141) of the pulmonologists who personally perform measurements using calipers (58 %, 141/243) did so in a manner that conformed.

**Discussion**

The present study evaluates the awareness of and conformance to the Fleischner recommendations for SSN

**Table 3** Chosen management strategies per case by pulmonologists or pulmonology residents

	Case 1		Case 2		Case 3		Case 4	
	SSN	No SSN	SSN	No SSN	SSN	No SSN	SSN	No SSN
Management strategy	224 *	19	187 *	56	180 *	63	33	210 *
Nothing	2 (1 %)	7 (37 %)	1 (1 %)	27 (48 %)	1 (1 %)	37 (59 %)	3 (9 %)	<b>158 (75%)</b> +
4-week FU	21 (9 %)	2 (11 %)	41 (22 %)	5 (9 %)	10 (6 %)	4 (6 %)	2 (6 %)	3 (1 %)
3-month FU	94 (42 %)	-	<b>80 (43%)</b> +	11 (20 %)	29 (16 %)	2 (3 %)	16 (48 %)	20 (10 %)
6-month FU	17 (8 %)	3 (16 %)	7 (4 %)	4 (7 %)	2 (1 %)	2 (3 %)	7 (21 %)	20 (10 %)
24-month FU	7 (3 %)	2 (11 %)	2 (1 %)	-	-	2 (3 %)	2 (6 %)	4 (2 %)
12, 24 and 36-month FU	<b>26 (12%)</b> +	3 (16 %)	9 (5 %)	3 (5 %)	5 (3 %)	1 (2 %)	2 (6 %)	5 (2 %)
Other modality	38 (17 %)	2 (11 %)	35 (19 %)	4 (7 %)	<b>97 (54%)</b> +	13 (21 %)	-	-
Resection	13 (6 %)	-	7 (4 %)	1 (2 %)	<b>29 (16%)</b> +	1 (2 %)	1 (3 %)	-
Other	6 (3 %) <sup>a</sup>	-	5 (3 %) <sup>b</sup>	1 (2 %) <sup>c</sup>	7 (4 %) <sup>d</sup>	1 (2 %)	-	-
Overmanagement	187 (83 %)	N/A	96 (51 %)	N/A	-	N/A	N/A	52 (25 %)
Undermanagement	11 (5 %)	N/A	11 (6 %)	N/A	54 (30 %)	N/A	N/A	-

Case 1 represents a persistent, pure ground-glass SSN (15x14 mm); case 2 shows a new part-solid SSN with a small solid component (total lesion size 20x16 mm, solid component size 3 × 4 mm); case 3 shows a persistent part-solid SSN with a large solid component (total lesion size 25 × 25 mm, solid component size 12 × 8 mm); and case 4 presents a triangular solid nodule with a perifissural location (10x5 mm)

FU = follow-up; \* = correct characterization of the pulmonary nodule; + = correct management strategy according to Fleischner recommendations for SSN management; <sup>a</sup> = two respondents did not provide management recommendation; <sup>b</sup> = one respondent did not provide management recommendation; <sup>c</sup> = one respondent did not provide management choice; <sup>d</sup> = four respondents did not provide management choice

**Table 4** Awareness of Fleischner recommendations for SSN management among respondents

	Radiologists			Pulmonologists		
	Aware	Unaware		Aware	Unaware	
All respondents	111/119 (93 %)	8/119 (7 %)		169/243 (70 %)	74/243 (30 %)	
Academic	63/67 (94 %)	4/67 (6 %)	<i>P</i> = 0.09	110/155 (71 %)	45/155 (29 %)	<i>P</i> = 0.52
Non-academic	48/52 (92 %)	4/52 (8 %)		59/88 (67 %)	29/88 (33 %)	
Teaching practice	97/102 (95 %)	5/102 (5 %)	<i>P</i> = 0.09	129/182 (71 %)	53/182 (29 %)	<i>P</i> = 0.44
Non-teaching practice	14/17 (82 %)	3/17 (18 %)		40/61 (66 %)	21/61 (34 %)	
Less experienced (<5 years)	17/21 (81 %)	4/21 (19 %)	<i>P</i> = 0.03	43/68 (63 %)	25/68 (37 %)	<i>P</i> = 0.18
More experienced (5 or more)	94/98 (96 %)	4/98 (4 %)		126/175 (72 %)	49/175 (28 %)	
Smaller practice (<10 specialists)	30/31 (97 %)	1/31 (3 %)	<i>P</i> = 0.68	112/155 (72 %)	43/155 (28 %)	<i>P</i> = 0.22
Larger practice (10 or more)	81/88 (92 %)	7/88 (8 %)		57/88 (65 %)	31/88 (35 %)	
Dept. without chest fellowship-trained specialist	29/31 (94 %)	2/31 (6 %)	<i>P</i> = 1.00	N/A		
Dept. with at least 1 chest-fellowship specialist	82/88 (93 %)	6/88 (7 %)				
Number SSNs encountered (10 or less p/y)	16/20 (80 %)	4/20 (20 %)	<i>P</i> = 0.03	68/113 (60 %)	45/113 (40 %)	<i>P</i> < 0.01
Number SSNs encountered (>10 p/y)	95/99 (96 %)	4/99 (4 %)		101/130 (78 %)	29/130 (22 %)	

Dept. = Department; SSN = Subsolid pulmonary nodule

management among radiologists and pulmonologists in clinical practice. Our survey shows that over two years after publication, awareness is widespread. Nevertheless, conformance to the FR varies considerably and overmanagement with more follow-up or additional diagnostic procedures not indicated is common.

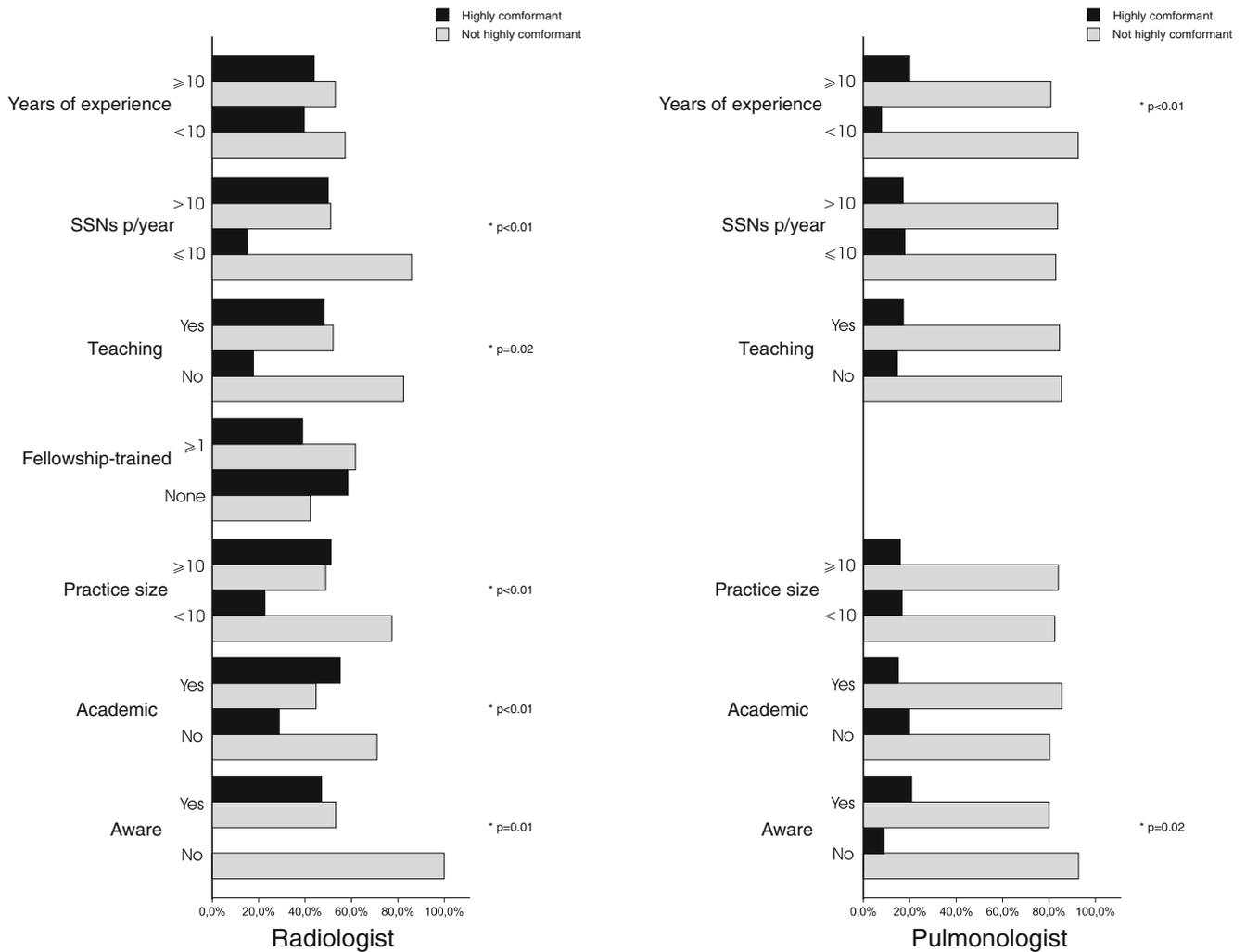
To our knowledge, this is the first study to evaluate the awareness of and conformance to the Fleischner recommendations for SSN management. Previously, a number of survey studies have been performed to evaluate management of small, solid pulmonary nodules [11–15]. A shared conclusion of these studies was that there is high heterogeneity among specialists with respect to guideline conformance. Contrarily, a high percentage of respondents reported awareness of the guidelines [11]. In our study, which included both radiologists and pulmonologists, the results are comparable. Despite high awareness and straightforward clinical scenarios, between 31 and 69 % of the radiologists chose management recommendations not corresponding to the FR. Among pulmonologists, awareness was significantly lower and management of SSNs even more variable, which may well be due to the radiological origin of the recommendations. Most interestingly, we also observed a variable conformance to the FR within individual readers for the four lesions types.

There may be several explanations for management deviations: (1) respondents may be aware of the FR but apply them erroneously, use a deviating, locally developed protocol or no clearly described method at all. It remains unclear to which extent one or more of these factors contributed to the variability we observed. Besides the Fleischner recommendations for SSN management, other management standards are publicly available, with LUNG-RADS or ACCP guidelines being the most important [16, 17]. Interestingly however, among our

respondents only a few individuals (N = 7) reported to apply these guidelines in daily practice. (2) Respondents may not agree with the FR and therefore deliberately chose a deviating strategy. After all, the FR are mainly based on expert opinion due to limited availability of data, especially in a non-lung cancer screening setting. In our study, non-conformance was surprisingly mostly categorized as overmanagement. Therefore, disagreement due to the conservativeness of the FR does not seem to be a major explanatory factor for the heterogeneity. (3) Some deviation in management might be erroneously due to respondents who overread or ignored the presented clinical scenarios (e.g., new versus persistent SSN). This may at least partly explain why overmanagement was highest for the persistent, pure ground-glass nodule, with the description ‘persistent’ as the clue for yearly serial follow-up and not a 3-month follow-up scan.

#### Awareness and conformance

Awareness of the Fleischner recommendations for SSN management was significantly higher in clinicians with higher exposure to SSNs, and in more experienced radiologists. However, it has to be noted that awareness among radiologists was generally very high (ie. only eight individuals reported unawareness), limiting statistical power. Guideline awareness among pulmonologists—which was significantly lower and only showed association to SSN exposure—has not been assessed previously. Previously reported factors associated with guideline conformance in solid nodule management included awareness of the guidelines, presence of a written management policy, working in a teaching practice, fellowship training in cardiothoracic radiology (either personally or a direct colleague), and years of experience [11, 13, 14]. Our



**Fig. 3** Radiologists and pulmonologists background characteristics in association with high conformance to the Fleischner recommendations for SSN management. The figure shows the percentage of radiologists and pulmonologists that showed high conformity (correct management strategy in three or four out of four cases). In radiologists, high

conformance was significantly associated with SSN exposure, teaching residents, working in a larger practice (≥10 specialists), working in an academic centre, and awareness of the FR. In pulmonologists, high conformity was associated with more experience (≥10 years) and awareness of the FR

results are largely comparable, with the exception that we did not find an influence of experience or fellowship-training in radiologists. This might be due to the fact that SSNs and their management are a relatively new entity, in which the more experienced clinicians have not yet developed their own long-standing practice patterns in solid nodule management [11]. Adding to what was previously discussed in the literature, we showed that higher exposure is associated with conformance.

**Over- and undermanagement**

The surprisingly strong tendency towards overmanagement is an important finding because unnecessary scans and invasive procedures lead to extra costs, radiation exposure, and potentially, to procedure-related risks. On the other hand, undermanagement is also a very important issue. It may lead

to unnecessary morbidity and mortality caused by advanced tumour stages. The latter, however, is still under discussion and more results from long-term outcome studies are needed, given the mainly indolent and slowly progressing nature of SSNs.

We found that overmanagement according to the FR was common among both radiologists and pulmonologists (18–58 % and 25–83 %, respectively), which is in line with results from the previous studies in solid nodule management, which reported overmanagement in 39–62 % [11] and 17–93 % [15]. Pulmonologists showed a stronger tendency towards overmanagement compared to radiologists, including invasive procedures as biopsy and resection. The reason for this remains unclear based on our results, but might be related to their reported lack of confidence in SSN management, with tissue diagnosis and a definite answer as the safest option.

On the other hand, we found undermanagement for the persistent part-solid subsolid lesion by both groups of respondents. This type of lesion, if persistent and demonstrating a solid component exceeding 5 mm, is considered highly suggestive for invasive adenocarcinoma. Nevertheless, 33 % of radiologists and 54 % of pulmonologists would have not recommended an immediate (invasive) work-up. This indicates either insufficient knowledge about the meaning of this type of lesion or the desire to avoid overdiagnosis by at least a subgroup of colleagues.

As mentioned above, some deviation in management may be erroneously due to respondents overlooking or ignoring clinical information on nodule persistence. This seems most relevant in case 1, in which 33 and 42 % of the radiologists and pulmonologists, respectively, called for a 3-month follow-up interval (which is indicated in the case of a new nodule) instead of the indicated serial annual follow-up (in the case of a persistent SSN). To a lesser extent, this might also account for some of the undermanagement in case 3, in which 19 and 16 % of the respondents chose a 3-month follow-up interval instead of further work-up. Determining the true impact of respondents noting persistence in the presented cases is impossible, but over- and undermanagement may thus be somewhat lower than presented. Nevertheless, this argument cannot fully explain the large heterogeneity throughout and between the cases and respondents. Moreover, previous guideline conformance studies showed comparable percentages of non-conformance. We believe that the heterogeneity in SSN management found in this study is mainly caused by personal interpretation and an inherent tendency to adjust guidelines by individual clinicians.

### Measurements of nodule dimensions

We further found that only a small minority of respondents obtain transverse measurements in two dimensions, as proposed in the Fleischner document. Most indicated that they measure the single maximum nodule diameter in either the axial or any other plane. In our study the influence of our finding was likely limited given the small number of nodules and a solid component size clearly under or over the threshold of 5 mm (case 2 and 3). Also, the influence of our finding in general is probably limited, given that one should only determine whether the SSN or its solid component is  $\leq 5$  mm or  $> 5$  mm. On the contrary, for the evaluation of solid pulmonary nodules where a similar measurement technique should be used and classification into four different size categories is required ( $< 4$  mm, 4–6 mm, 6–8 mm and  $< 8$  mm; [18]), this may well be of far more importance.

The strength of the current study is that we succeeded in including a sufficient number of both radiologists and pulmonologists. Given that in clinical practice detection and follow-up of subsolid pulmonary nodules is not a

monodisciplinary affair, it is important to obtain information on SSN management in both groups involved. Also, we were able to include both single-slice and animated multi-slice images of the nodules in the online questionnaire. We therefore also tested knowledge on nodule interpretation, which more closely resembles clinical practice than a written clinical scenario, as previously used in other survey studies on solid nodule management.

Our study also has some limitations. First, as with any survey there might be a response bias, which can neither be excluded nor quantified. However, in case a response bias was introduced, we believe it is far more likely that there has been weighting towards respondents with an affinity for subsolid nodules than for those without. If so, our results on awareness and conformance are probably higher than in reality. Second, due to technical reasons we only included solitary SSNs in the survey, while the FR also includes management of multiple subsolid nodules. Since management recommendations between solitary and multiple SSNs do not differ significantly and are both part of the same Fleischner document, we believe our study design is nevertheless valid to assess the presented study purpose.

In conclusion, although awareness of the Fleischner recommendations for SSN management is widespread among both radiologists and pulmonologists, management choices differ substantially from these recommendations, and over- and undermanagement are common.

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