Association of Unfinished Root Canal Treatments with the Risk of Pneumonia Hospitalization

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Abstract

Introduction: The objective of root canal treatments (RCTs) is to control pulpal diseases and salvage infected teeth by eradicating microorganisms within the root canal system. However, an unfinished RCT can leave a space for bacterial accumulation, which can leak into the oral cavity and then aspirate into the lower respiratory tract and the lungs, causing infection. This study investigated the association of unfinished RCTs with the possible risk of pneumonia hospitalization using a nationwide population-based database. **Methods:** After a matching process, we recruited 116,490 subjects who received an initiated RCT and had no history of pneumonia before 2005 and observed until the end of 2011. An unfinished RCT was operationally defined as an endodontic session that was started on a tooth but had no subsequent completion records. Cox proportional hazards models and subgroup analyses were used to estimate the association of unfinished RCTs on the risk of pneumonia hospitalization. **Results:** In total, 1285 subjects were hospitalized for pneumonia during 2005 to 2011 with an overall pneumonia hospitalization incidence rate of 0.22% per person year. After adjusting for confounding factors, the adjusted pneumonia hospitalization hazard ratio for subjects who had unfinished RCTs was 1.40 (95% confidence interval, 1.24–1.59) compared with subjects without unfinished RCTs ($P < .0001$). For middle-aged patients, the hazard ratio was 1.81 (95% confidence interval, 1.45–2.24). **Conclusions:** Patients with unfinished RCTs had a higher risk of pneumonia hospitalization. Thus, dentists are advised to complete endodontic treatments once started. *(J Endod 2017;43:29–35)*

Key Words

Pneumonia, survival analysis, Taiwan national health insurance research database, unfinished root canal treatment

Significance

Patients with unfinished root canal treatments were associated with a higher risk of future pneumonia hospitalization, especially middle-aged patients. Dentists and patients should cooperate together to finish the treatment course once started.

Pneumonia is an infectious inflammatory disease of the lung involving pulmonary parenchyma. It is the most common fatal nosocomial infection and is associated with a considerable amount of morbidity and mortality, causing 3.2 million human deaths worldwide in 2011 (1). In Taiwan, because of its mortality rate of 44.2 deaths per 100,000 person years, pneumonia ranked the fourth highest cause of death in 2014 (2).

The oral cavity hosts highly diverse microbiota (3). In other words, because of its humidity and temperature, the oral cavity provides an appropriate environment for the development of organized bacterial communities containing diverse species with varying degrees of virulence (4). In addition to generating dental problems, oral microorganisms have been implicated as crucial agents causing pneumonia in recent years (5–7). Four routes of connecting oral microorganisms to pneumonia have been suggested:

1. Aspiration of oropharyngeal secretions, food, or gastric contents;
2. Inhalation of infectious aerosols;
3. Spread of infections from contiguous sites; and
4. Hematogenous spread from extrapulmonary sources of infection (8).

Dental caries and periodontal disease are the 2 major infectious diseases caused by oral microorganisms. Pulpal diseases occur when bacteria penetrate through the dentinal tubules to reach the pulp; these require root canal treatment (RCT) to remove bacterial and tissue debris from the root canal system and salvage the tooth. Although it is difficult to consistently and totally clean root canal systems (9), the goal of obturation is to provide an impermeable fluid-tight seal within the entire system in order to prevent coronal and apical microleakage by directly and ecologically controlling the infection (10). Patients with unfinished RCT may have poorer oral health (11), which is responsible for a higher pneumonia risk compared with those with superior oral health (12). However, the available evidence regarding the association of unfinished RCTs with future pneumonia events is scant. This study investigated the possible effects of unfinished RCT and the risk of pneumonia hospitalization using a nationwide population-based database.

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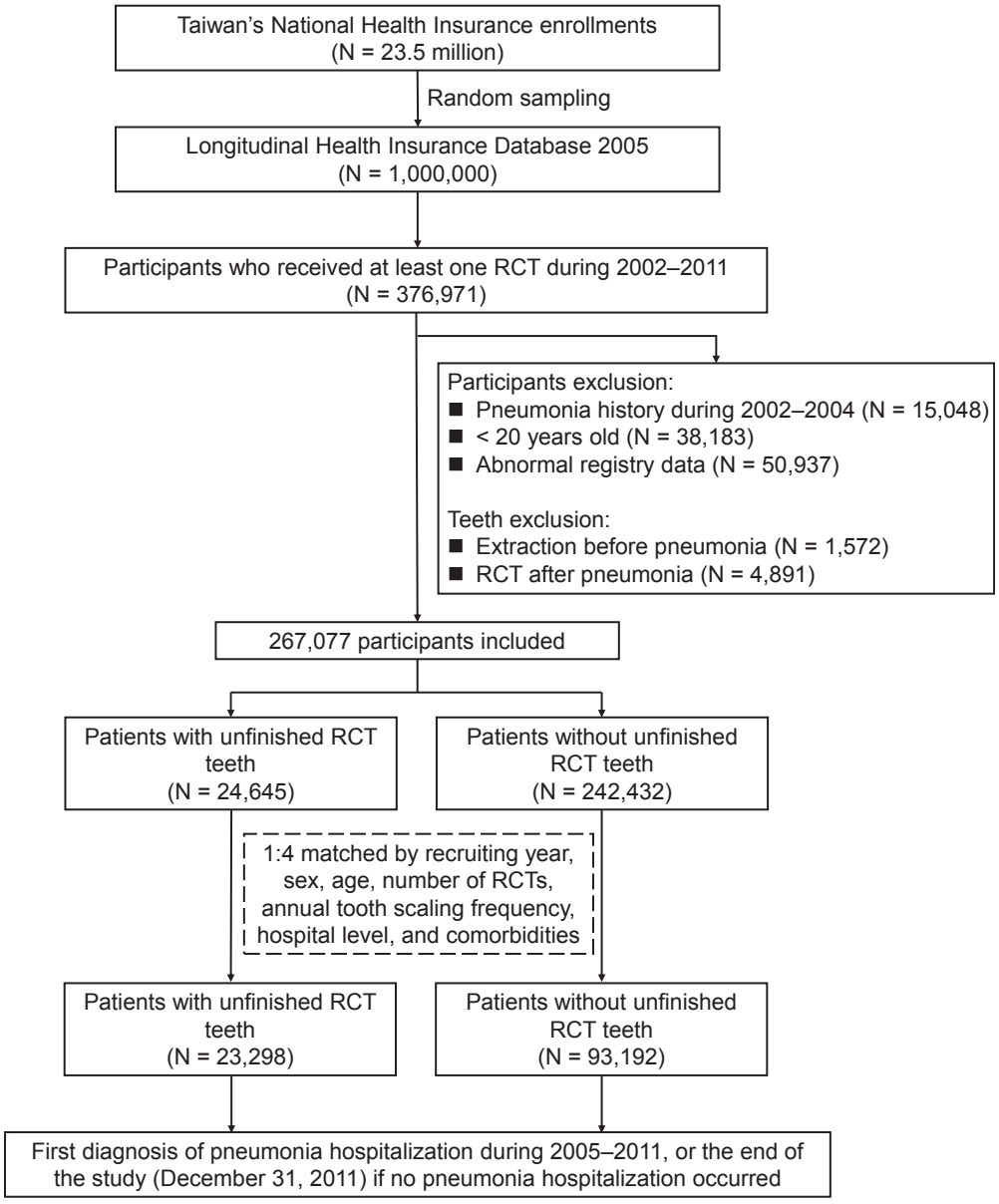

Figure 1. A flowchart of the selection of study subjects from Taiwan's National Health Insurance Research Database.

Material and Methods

Study Database

The Taiwan National Health Insurance program, which was implemented in 1995, provides health care through mandatory health insurance and covers approximately 99% of the 23.5 million residents of Taiwan. The present study extracted the records of the Longitudinal Health Insurance Database 2005, which includes the registration data as well as the dental and medical claims data from 2002 to 2011 of 1,000,000 randomly sampled beneficiaries from all 2005 National Health Insurance beneficiaries. No statistically significant differences have been reported in age or sex distribution between the sampled group and the entire set of enrollees. Many longitudinal epidemiological endodontic studies have used this database (13, 14).

Study Population

The present retrospective cohort study included all adult subjects aged ≥20 years receiving at least 1 RCT during 2002 to 2011 and having no outpatient or inpatient history of pneumonia, lung abscess, or empyema diagnosis during 2002 to 2004 (Fig. 1) (15). The start of each endodontic therapy session was identified by a specific treatment code (90015C), and its end was identified by completion codes (90001C, 90002C, 90003C, 90019C, and 90020C for 1-, 2-, 3-, 4-, and ≥5-canal systems, respectively), which required supporting evidence, such as periapical radiographic films for claims. An unfinished RCT was operationally defined as an RCT that was started on a tooth but had no subsequent completion record. Teeth extracted before pneumonia hospitalization were excluded. In addition, subjects with abnormal registry data, such as missing sex data, inconsistent birth data, or withdrawal from the insurance program during 2002 to 2011, were excluded. This study was approved by the Institutional Review Board of National Yang-Ming University, Taipei, Taiwan (approval number: YM102042 E).

Among the final 267,077 subjects, those who had at least 1 unfinished RCT tooth were stratified into the exposed group (n = 24,645). The nonexposed group (n = 242,432) was composed of subjects in

TABLE 1. A Comparison of the Demographic and Clinical Characteristics and Pneumonia Hospitalization Incidence Rates of Study Participants Who Had Unfinished Root Canal Treatment (RCT) with Those Who Did Not after 1:4 Matching Recruited from Taiwan's National Health Insurance Research Database During 2002 to 2011

Variables	With unfinished RCT *n* = 23,298		Without unfinished RCT *n* = 93,192		*P* value
	N (%)	IR (%/PY)	N (%)	IR (%/PY)	
Pneumonia hospitalization	329 (1.41)	0.29	956 (1.03)	0.20	<.0001
Mean observed days (SD)	1783.7 (1126.5)		1882.6 (1071.7)		.007
Sex					
Female	12,730 (54.64)	0.26	50,386 (54.07)	0.16	.12
Male	10,568 (45.36)	0.32	42,806 (45.93)	0.24	
Age					
20–40	10,322 (44.30)	0.12	39,977 (42.90)	0.08	<.0001
41–60	9004 (38.65)	0.27	37,763 (40.52)	0.15	
>60	3972 (17.05)	0.81	15,452 (16.58)	0.67	
Mean number of initiated RCTs from 2002–2011 (SD)	2.33 (1.68)		2.37 (1.87)		.0004
Annual tooth scaling frequency during 2002–2011					<.0001
>1	1612 (6.92)	0.36	5054 (5.42)	0.17	
0–1	19,555 (83.93)	0.29	79,507 (85.32)	0.20	
0	2131 (9.15)	0.27	8631 (9.26)	0.24	
Hospital level					.0002
Hospitals	1421 (6.10)	0.49	6315 (6.78)	0.39	
Local Clinics	21,877 (93.90)	0.28	86,877 (93.22)	0.19	
Cerebrovascular disease					.11
Yes	1039 (4.46)	1.24	4386 (4.71)	1.00	
No	22,259 (95.54)	0.24	88,806 (95.29)	0.16	
Chronic kidney disease					.44
Yes	555 (2.38)	1.05	2301 (2.47)	0.88	
No	22,743 (97.62)	0.27	90,891 (97.53)	0.18	
Ischemic heart disease					.09
Yes	1786 (7.67)	0.86	7460 (8.00)	0.65	
No	21,512 (92.33)	0.24	85,732 (92.00)	0.16	
Chronic obstructive pulmonary disease					.46
Yes	277 (1.19)	3.49	1164 (1.25)	2.52	
No	23,021 (98.81)	0.25	92,028 (98.75)	0.17	
Asthma					.87
Yes	848 (3.64)	1.35	3413 (3.66)	0.82	
No	22,450 (96.36)	0.25	89,779 (96.34)	0.18	
Diabetes mellitus					.001
Yes	2434 (10.45)	0.74	10,437 (11.20)	0.51	
No	20,864 (89.55)	0.23	82,755 (88.80)	0.16	
Hypertension					<.0001
Yes	5176 (22.22)	0.63	21,841 (23.44)	0.45	
No	18,122 (77.78)	0.19	71,351 (76.56)	0.12	
Liver diseases					.79
Yes	2070 (8.88)	0.60	8333 (8.94)	0.35	
No	21,228 (91.12)	0.26	84,859 (91.06)	0.18	
Neurologic diseases					.60
Yes	4575 (19.64)	0.50	18,160 (19.49)	0.29	
No	18,723 (80.36)	0.24	75,032 (80.51)	0.18	
Rheumatologic diseases					.54
Yes	532 (2.28)	0.62	2191 (2.35)	0.33	
No	22,766 (97.72)	0.28	91,001 (97.65)	0.20	
Tobacco use disorder					.71
Yes	162 (0.70)	0.45	627 (0.67)	0.37	
No	23,136 (99.30)	0.29	92,565 (99.33)	0.20	

IR, incidence rate; PY, person year; RCT, root canal treatment; SD, standard deviation.

whom a ratio of 1:4 matched recruiting year; sex; age; number of initiated RCTs; annual tooth scaling frequency; hospital level; and significant underlying systemic diseases using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) codes including cerebrovascular diseases (*ICD-9-CM*: 430–438), chronic kidney diseases (*ICD-9-CM*: 580–589), ischemic heart disease (*ICD-9-CM*: 410–414), chronic obstructive pulmonary diseases (*ICD-9-CM*: 496), asthma (*ICD-9-CM*: 493), diabetes mellitus (*ICD-9-CM*: 250, including types I and II), hypertension (*ICD-9-CM*: 401–405), liver diseases (*ICD-9-CM*: 570–573), neurologic diseases (*ICD-9-CM*: migraines 346, headaches 784, and Parkinson disease 332), rheumatologic diseases (*ICD-9-CM*: rheumatoid arthritis 714, systemic lupus erythematosus 710, and ankylosing spondylitis 720), and tobacco use disorder (*ICD-9-CM*: 305.1) (16, 17). To increase the validity of diagnoses in our administrative data set, we included only outpatients with 3 or more repeat diagnoses of the aforementioned comorbidities during 2005 to 2011. After the matching process, 116,490 subjects were recruited as the study population for further analysis (Fig. 1). The entry date for the exposed group was the start date of the first unfinished RCT; for the nonexposed group, the entry date was the start date of the first RCT. The subjects were followed until the first pneumonia hospitalization (*ICD-9-CM*:

480–483, 485–486, and 487.0) during 2005 to 2011 or the end of the study (December 31, 2011) if no pneumonia hospitalization occurred, leading to a maximum observation period of 10 years.

Statistical Analysis

The differences of distribution between the exposed and nonexposed groups in pneumonia hospitalization incidence, demographic and clinical characteristics, and mean observed days were analyzed using Student *t* tests and Mantel-Haenszel chi-square tests. The log-rank test and multivariate Cox proportional hazards models were used to estimate the effects of unfinished RCTs on the risk of pneumonia hospitalization during 2005 to 2011. Potential confounding factors, including sex, age, number of initiated RCTs, annual tooth scaling frequency, and systemic diseases, were adjusted in the Cox regression analyses. Furthermore, ages were stratified into 3 groups (20–40, 41–60, and >60 years) for subgroup analysis. All statistical tests were performed using SAS (version 9.3; SAS Institute Inc, Cary, NC), and the level of significance was $P < .05$ (2 tailed).

Results

Among the 116,490 subjects who received at least 1 RCT during 2002 to 2011 and without a pneumonia history before 2005, 1285 were hospitalized for pneumonia during 2005 to 2011, yielding a total incidence rate of 0.22% per person year. The pneumonia hospitalization incidence rate for subjects with unfinished RCTs was 0.29% per person year, which was significantly higher than that for subjects without unfinished RCTs (0.20%, $P < .0001$; Table 1).

Table 1 presents the distributions of baseline characteristics of subjects with and without unfinished RCT teeth after the 1:4 matching process. Sex and most underlying systemic diseases were matched between the exposed and nonexposed groups ($P > .05$). On the other hand, 44.30% of the subjects with unfinished RCTs were 20–40 years of age, which was significantly higher than 42.90% of the subjects without unfinished RCTs ($P < .0001$). Patients with unfinished RCTs received an average of 2.33 initiated RCTs during 2002 to 2011, which was significantly fewer than the 2.37 RCTs received by those without unfinished RCTs ($P = .0004$); 6.92% of the subjects with unfinished RCTs had received tooth scaling more than once per year during 2002 to 2011, which was significantly more than the 5.42% of those without unfinished RCTs ($P < .0001$). In addition, compared with subjects with unfinished RCTs, a larger percentage of subjects without unfinished RCTs exhibited diabetes mellitus and hypertension ($P < .001$).

Figure 2 shows the cumulative hazard probabilities categorized by the presence of unfinished RCT teeth for pneumonia hospitalization. The pneumonia hospitalization hazard probability for subjects with unfinished RCTs after 10 years was 0.037, which was significantly higher than for those without unfinished RCTs (0.022, $P < .0001$). In the Cox proportional hazards regression analysis, the crude hazard ratio (HR) revealed that the pneumonia hospitalization incidence was 45%-fold higher (95% confidence interval [CI], 1.28–1.65) for subjects with unfinished RCTs than that for subjects without unfinished RCTs. After adjusting for potential confounding factors including age, sex, number of initiated RCTs, annual tooth scaling frequency, hospital level, and systemic diseases, the adjusted HR for pneumonia hospitalization for subjects with unfinished RCTs was 1.40 (95% CI, 1.24–1.59) compared with those without unfinished RCTs (Table 2). When stratified by age, subgroup analysis showed that unfinished RCTs had the strongest association among middle-aged subjects (aged 41–60 years; adjusted HR = 1.81; 95% CI, 1.45–2.24; $P < .0001$), a modest association among younger subjects (aged 20–40 years; adjusted HR = 1.48; 95% CI, 1.11–1.97; $P = .007$), and the least association among older subjects (aged >60 years; adjusted HR = 1.17; 95% CI, 0.97–1.41; $P = .099$). The multivariate Cox proportional hazard regression model analysis indicated that subjects who had unfinished RCTs were associated with a higher risk of future pneumonia hospitalization, especially patients 41–60 years of age.

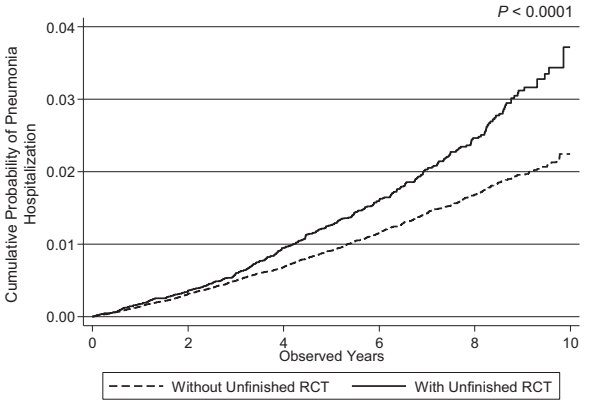

Figure 2. Cumulative hazard probabilities for pneumonia hospitalization categorized by having unfinished RCTs between 2005 and 2011.

Discussion

The present study, which included subjects who received at least 1 initiated RCT without a related history of pneumonia in the past 3 years, was the first population-based study to investigate the possible association between unfinished RCTs and the risk of pneumonia hospitalization. The results revealed that subjects who had unfinished RCTs were associated with a higher risk of future pneumonia hospitalization, especially middle-aged patients.

The pneumonia hospitalization incidence rate in this study was 0.22% per person year among subjects with at least 1 RCT. This rate was slightly lower than that reported by Lin et al (18), who extracted data from the same database from 1998 to 2005 and reported a hospitalization rate of 0.32%–0.46% per person year among adult patients aged ≥18 years. In the present study, subjects with a history of pneumonia, lung abscess, and empyema before 2005 were excluded; therefore, the hospitalization rate in the present study may have been underestimated. Su et al (15) validated 2002 to 2011 data from the Longitudinal Health Insurance Database 2000 with clinical information and imaging records and showed high sensitivity (94.7%) in identifying pneumonia hospitalization events using *ICD-9-CM* codes compared with the consensus guidelines. However, the *ICD-9-CM* codes, mainly classified by microorganism (bacteria, virus, and others), did not enable the identification of pneumonia as a community-acquired pneumonia or nosocomial pneumonia, including ventilator-acquired pneumonia.

Although the causative pathogens are distinct, both community-acquired pneumonia (commonly caused by nasopharyngeal commensals such as *Streptococcus pneumoniae* and *Haemophilus influenzae*) and nosocomial pneumonia (commonly caused by gram-negative and multiresistant environmental bacteria such as *Pseudomonas* and *Acinetobacter* species and *Staphylococcus aureus* from the oropharynx) are associated with dental health status. Regarding community-acquired pneumonia, Almirall et al (19) conducted a population-based study in Spain and indicated that participants who visited dentists in the previous month had a protective effect against community-acquired pneumonia (adjusted odds

TABLE 2. Results of the Cox Regression Analyses Conducted to Identify Risk Factors for Pneumonia Hospitalization Based on Taiwan's National Health Insurance Research Database Entries from 2005 to 2011

Variables		Total (*N* = 116,490)	Subgroup analysis		
			Age 20–40 (*n* = 50,300)	Age 41–60 (*n* = 46,766)	Age >60 (*n* = 19,424)
		Hazard ratio (95% CI)	Hazard ratio (95% CI)	Hazard ratio (95% CI)	Hazard ratio (95% CI)
Age	41–60 vs 20–40	1.49 (1.26–1.77)‡			
	>60 vs 20–40	3.51 (2.91–4.22)‡			
Sex	Male vs female	1.16 (1.04–1.30)†	1.03 (0.79–1.34)	1.01 (0.83–1.24)	1.33 (1.13–1.57)†
Unfinished RCTs	Yes vs no	1.40 (1.24–1.59)‡	1.48 (1.11–1.97)†	1.81 (1.45–2.24)‡	1.17 (0.97–1.41)
Number of initiated RCTs	+1	0.88 (0.86–0.91)‡	0.87 (0.80–0.95)†	0.89 (0.84–0.94)‡	0.87 (0.84–0.91)‡
Annual tooth scaling Frequency during 2002–2011	0–1 vs 0	0.94 (0.79–1.12)	0.91 (0.61–1.37)	1.18 (0.83–1.69)	0.88 (0.70–1.11)
	>1 vs 0	0.89 (0.67–1.18)	0.61 (0.27–1.36)	1.35 (0.83–2.19)	0.75 (0.50–1.12)
Hospital level	Hospitals vs local Clinics	1.36 (1.14–1.62)†	1.62 (1.01–2.59)*	1.36 (0.96–1.93)	1.32 (1.06–1.65)*
Cerebrovascular disease	Yes vs no	2.06 (1.78–2.38)‡	3.44 (1.38–8.56)†	1.98 (1.43–2.73)‡	2.11 (1.79–2.49)‡
Chronic kidney disease	Yes vs no	1.62 (1.34–1.95)‡	1.43 (0.44–4.54)	2.03 (1.40–2.93)†	1.56 (1.25–1.95)‡
Ischemic heart disease	Yes vs no	1.23 (1.06–1.41)‡	1.85 (0.78–4.38)	1.36 (1.03–1.79)*	1.18 (0.99–1.39)
Chronic obstructive pulmonary disease	Yes vs no	3.77 (3.15–4.51)†	—	5.40 (3.60–8.12)‡	3.81 (3.11–4.66)‡
Asthma	Yes vs no	2.02 (1.71–2.40)‡	3.67 (2.31–5.83)‡	2.29 (1.66–3.16)‡	1.71 (1.38–2.12)‡
Diabetes mellitus	Yes vs no	1.44 (1.26–1.65)‡	1.23 (0.64–2.37)	1.84 (1.46–2.32)‡	1.27 (1.07–1.50)†
Hypertension	Yes vs no	1.14 (0.98–1.31)†	1.18 (0.70–1.98)	1.12 (0.89–1.40)	1.07 (0.88–1.30)
Liver diseases	Yes vs no	1.39 (1.19–1.61)‡	1.83 (1.20–2.80)†	1.76 (1.39–2.23)‡	1.06 (0.85–1.33)
Neurologic diseases	Yes vs no	1.30 (1.15–1.47)‡	1.84 (1.37–2.46)‡	1.34 (1.07–1.68)*	1.12 (0.95–1.33)
Rheumatologic diseases	Yes vs no	1.18 (0.90–1.55)	1.47 (0.60–3.57)	1.31 (0.80–2.13)	1.15 (0.81–1.64)
Tobacco use disorder	Yes vs no	1.33 (0.81–2.19)	1.47 (0.47–4.61)	2.39 (1.26–4.51)†	0.50 (0.16–1.55)

CI, confidence interval; RCT, root canal treatment.

*.01 ≤ *P* < .05.

†.0001 ≤ *P* < .01.

‡*P* < .0001.

ratio = 0.69; 95% CI, 0.50–0.95). The authors hypothesized that this result was caused by favorable oral hygiene. Regarding nosocomial pneumonia, Sjogren et al (20) performed a systematic review in 2008 and indicated that approximately 1 in 10 cases of deaths from pneumonia may be prevented by improving oral hygiene. To summarize, patients with poor oral health have a 1.2- to 9.6-fold higher pneumonia risk compared with those with superior oral health according to a 2006 systematic review by Azarpazhooh and Leake (12). According to the results of Lin et al's recent study, patients with unfinished RCTs might be surrogates for poorer oral health (14). Oral and respiratory bacteria in the dental plaque might be shed into the saliva and then aspirated into the lower respiratory tract and the lungs to cause infection (21); alternatively, cytokines and enzymes induced from the periodontal inflamed tissues by the oral biofilms are likely transferred into the lungs where they may stimulate local inflammatory processes preceding colonization of pathogens and the actual lung infection (22, 23).

Another possible pathological mechanism resulting from an unfinished RCT is that the operated tooth may sustain a symptomatic infection caused by gram-negative anaerobic microorganisms (24, 25), including *Fusobacterium*, *Porphyromonas*, *Prevotella*, *Eubacterium*, and *Peptostreptococcus* (26). Although *S. pneumoniae* can cause approximately 50% of pneumonia cases (27), mixed infections involving 2 or more bacterial species are more likely to cause virulent pneumonia (28). Other anaerobes, such as *Bacteroides*, *Fusobacterium*, and *Peptostreptococcus*, have been recognized in some pneumonia cases (29), indicating that these anaerobic microorganisms can leak into the oral cavity through microleakages of the temporary restorations or spread out from the root canal system during treatment if a rubber dam is not used (30). Subsequently, these species can colonize in dental plaque within the oral cavity and enhance the pathogenic potential of other respiratory pathogens, affecting the initiation and progression of pneumonia (31–33).

In recent years, it has been generally accepted that oral microflora can play a specific role in the pathogenesis of pneumonia (28). However, the possible association between pulpal diseases and pneumonia remains unclear, and few studies have been published on this issue. In 2015, Laurence et al (7) analyzed the data from the Nationwide Emergency Department Sample for the year 2008 and revealed that pneumonia patients with endodontic or periodontal infections have a significantly higher risk for hospital admission (prevalence ratio = 1.19; 95% CI, 1.11–1.27) compared with those without these infections. Nevertheless, they did not perform further stratification analyses, and the possible role of endodontic or periodontal infections in pulpal diseases alone remains unknown. In our study, to minimize the confounding factors of periodontal disease and oral hygiene status, we added annual tooth scaling frequency to the multivariate model; after controlling for this factor, unfinished RCTs were independently associated with a higher risk of future pneumonia hospitalization.

In the multivariate Cox regression analyses, subjects older than 60 years were 3.51 times more likely to be hospitalized than younger subgroups, suggesting that age is an important risk factor (Table 2). However, we found a weaker association between unfinished RCTs and pneumonia hospitalization among subjects older than 60 years in the subgroup analysis (adjusted HR = 1.17; 95% CI, 0.97–1.41; *P* = .099; Table 2). This might be because the effect of aging and the subjects' systemic diseases superseded the influence of oral health status on pneumonia hospitalization. We could not directly determine the plaque index or periodontal status of each subject to reveal the prevalence of dental plaque and the increase in bacteria associated with the development of pneumonia; this may be a major limitation of the present study.

According to Lin et al's study (34), which extracted data from the same database from 2002 to 2004, the mean cost per pneumonia hospitalization was US $1957. If all endodontic courses can be finished, it is probable that fewer subjects would have future pneumonia hospitalizations, saving some expansion of health care spending. However, the current secondary analysis did not allow us to make any causal relationships, and more evidence is needed to provide further financial discussions. According to Caplan and White's study in 2001 (11), patients whose teeth were symptomatic and had more missing first molars at access tended to have an unfinished RCT course at a dental health maintenance office. Although the current study did not allow us to retrieve the medical record from the database so we did not know whether patients had symptoms or not, it is important that dentists and patients should cooperate to finish the treatment course once started, and dentists should pay more attention to the patients who had symptoms over the infected tooth and inferior oral health.

Other limitations should also be considered. First, data regarding some crucial lifestyle risk factors for pneumonia hospitalization, such as smoking, alcohol abuse, being underweight, and having regular contact with children, were unavailable in the study database; this may have resulted in insufficient adjustment of the potential confounding factors. Therefore, the causal relationship remains uncertain. Second, we did not consider seasonal variation of pneumonia admissions because it is obviously associated with lower ambient temperatures (18). However, when we analyzed the frequency of pneumonia hospitalizations by month, we could not identify any seasonal variation trend. It might be because we used a matching method to create our cohort so it could not represent the whole population in Taiwan. Third, the database did not contain some clinical parameters of RCTs such as the irrigant used and cleaning and shaping techniques; therefore, we could not clearly identify the inflammatory status, number of root canals, volume of root canal space, species of the microorganisms, or reasons for each unfinished RCT tooth. In addition, we could not ensure the absence of bacterial or pulpal inflammation in the completed RCTs. Nevertheless, the results of the present study show a real-world pattern that provides dentists and patients with valuable information.

Conclusion

After adjusting for confounding factors including age, sex, number of initiated RCTs, annual tooth scaling frequency, hospital level, and systemic diseases, we observed that subjects with unfinished RCTs had a higher risk of future pneumonia hospitalization, especially middle-aged patients. Additional studies further evaluating the causal relationship between unfinished RCTs and subsequent pneumonia events are necessary.

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The authors deny any conflicts of interest related to this study.

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