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Original Article

Overview of dental radiology education for medical radiology students in Taiwan

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Abstract *Background/purpose:* In Taiwan, the formal education for cultivating medical radiation technologists began in 1965. However, there are very few dental radiology curricula in Taiwan's medical radiology schools. We investigated mainly the appearance of dental radiology education for medical radiology students in Taiwan.

Materials and methods: We used documentary analysis, a survey of dental radiology education, and secondary data analysis in this study to find the appearance of Taiwan's dental radiology education for medical radiology students.

Results: There were currently ten medical radiology schools. Among them, five offered independent curricula in their subject schedules and another five had dental radiology education included in their general medical radiology curricula. Of the 53 dental radiology teaching

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hospitals, 21 (39.62%) were medical centers and 25 (47.17%) were regional hospitals, and these large hospitals were concentrated in the northern region of Taiwan. These large dental radiology teaching hospitals offered more training hours of dental radiology internship for medical radiology students and had a higher availability for the medical radiology students.

Conclusion: In Taiwan, the current status of dental radiology curricula in the medical radiology schools is indeed seriously insufficient. A dental radiology education system should be established in the future, including the innovative dental radiology curricula developed for medical radiology students and more dental radiology curricula designed for dental students. This in turn can create new career options for medical radiology students and new practice directions for medical radiation technologists, and then expand their potential involvement in dental radiology.

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Introduction

Since the discovery of X-rays by Wilhelm Conrad Roentgen in late 1895 and a German dentist Otto Walkhoff obtained an X-ray film of his own teeth in early 1896, the application of X-rays for medical and dental photography has spread all over the world. In addition, the first X-ray machine for dental and jawbone disease diagnosis was manufactured by the current German company Siemens in 1905. Thus, the field of dental radiology has existed for more than 120 years.^{1–4}

Due to the fact that the Japanese colonial government directly introduced western medical system (including dentistry) to Taiwan during the Japanese colonial period (1895–1945), the development history of dental radiology in Taiwan was almost in step with the world. According to the provisions of the relevant laws and regulations for Taiwan's dentists during the Japanese colonial period on the professional names of the dental profession, dental X-ray was officially a dental profession in those days.^{4,5}

During the Japanese colonial period especially after the 1920s, Taiwan's dentists in hospitals or dental clinics might already use dental X-ray equipment for their practice. However, there was no concept of medical radiographers or dental radiographers during the Japanese colonial period. Besides dentists, dental technicians or dental assistants may also assist or participate in the use of dental X-ray equipment in those days. These personnel could be considered as the earliest form of dental radiographers in Taiwan. Thus, Taiwan's dental radiology is almost synchronized with the world and has at least 100-year history.^{4–9}

In modern medical care, the medical radiation technologists are the necessary manpower. However, in Taiwan, the establishment of a formal education system and a licensing system for medical radiation technologists has been delayed. In the early days, the training of medical radiation manpower in Taiwan was carried out by the form of hospital training classes or teacher-apprentice teaching. In terms of education system, the formal education for cultivating medical radiation technologists began in 1965 at Yuanpei Junior College (restructured into a university in 2005). At present, there are 10 medical radiology schools in Taiwan that cultivate medical radiation technologists.

Furthermore, in terms of licensing system, the formal national examination for licensing medical radiation technologists began in 1978. However, the legal system of Medical Radiation Technologists Act was established in 2000.¹⁰ Currently, there is no independent education system and licensing system for dental radiation technologists in Taiwan. Besides dentists, only medical radiation technologists can legally operate dental X-ray equipment. Even so, there are very few dental radiology curricula in Taiwan's medical radiology schools.

This study used documentary analysis, a survey of dental radiology education, and secondary data analysis to find the appearance of dental radiology education for medical radiology students in Taiwan. The results of this study would provide a reference of the dental radiology education system for medical radiology students.

Materials and methods

This study used documentary analysis, a survey of dental radiology education, and secondary data analysis to find the appearance of dental radiology education in medical radiology schools for their students in Taiwan. The brief history and the current status of dental radiology curricula in medical radiology schools were obtained from the websites of these medical radiology schools. In addition, the distribution of medical radiology schools and their academic programs, and the numbers of medical radiology schools, their newly-registered students, total students with official student status and graduates were obtained from the Ministry of Education.

The dental radiology department of National Taiwan University Hospital (NTUH) officially formatted a loose-organized group of medical radiation technologists who engaged in dental radiology in Taiwan. We carried out a census for dental radiology education survey through our informal and personal network of the dental radiology department of NTUH. In this survey, we investigated two questions related to our research: the first question was about whether your dental radiology department offered the curriculum of dental radiology internship for medical radiology students; and the second question was about how many training hours of dental radiology internship for

medical radiology students in your dental radiology department. At the beginning of 2022, we sent the investigation invitations and emailed the questions to the medical radiation technologists who were the heads of a hospital dental radiology department. The collection of survey data was completed by May 2022.

All secondary information and data were accessible from the respective websites. The research data of documentary analysis, dental radiology education survey, and secondary data analysis were stored in excel files and used for the descriptive statistics.

Results

The education system for medical radiology in Taiwan

In Taiwan, there were 10 medical radiology schools currently. Among them, only one was public (Table 1). There were six in general universities, three in technological universities, and one in a junior college. In addition to Shu-Zen Junior College of Medicine and Management which provided a five-year program and offered the Associate Bachelor degrees, the other nine medical radiology schools provided undergraduate programs for the Bachelor degrees and graduate programs for the Master degrees. Moreover, three medical radiology schools also provided graduate programs for the PhD degrees. Of these 10 medical radiology schools, three were located in the northern region, three in the central region, three in the southern region, and only one in the eastern region of Taiwan (Table 1).

The current status of dental radiology curricula in the medical radiology schools in Taiwan

According to the results of searching for the curriculum information from the websites of medical radiology schools, we found that the dental radiology was not a mainstream in the professional curricula of medical radiology schools in Taiwan. The dental radiology curriculum was special and rare among the subject schedules of medical radiology schools (Table 2). In this study, dental radiology curricula were divided into three types as follows: type 1: the dental radiology was an independent curriculum in the subject schedules of a medical radiology school; type 2: the dental radiology was not an independent curriculum in the subject schedules of a medical radiology school, but the content of dental radiology was included in the medical radiology curriculum; and type 3: the dental radiology internship was performed in the dental radiology department of a teaching hospital, and it was offered as part of the curriculum of diagnostic radiology internship.

Of the 10 medical radiology schools, only 5 offered type 1 curricula and 4 of the 5 were technological universities or colleges. These curricula were mainly electives and the number of credits for a single subject was 1–2 credits. However, the other 5 medical radiology schools did not offer type 1 curricula and they were all general universities. Their dental radiology curricula were offered as

type 2 curricula and all were compulsory. The number of course hours for dental radiology was only 2–4 h. Due to the regulations of the national medical radiation technologist examination, the diagnostic radiology internship of medical radiology students should also include the dental radiology internship. All medical radiology schools offered type 3 curricula. The dental radiology internship was performed in the dental radiology department of a teaching hospital qualified by the Ministry of Health and Welfare. The minimum number of internship weeks (hours) for diagnostic radiology internship was 12 weeks (480 h). However, the number of hours required for dental radiology internship was determined by each teaching hospital (Table 2).

The distribution of medical radiology junior college students and undergraduate students in Taiwan in 2021

According to the results of analyzing the statistics of the Ministry of Education, there were a total of 705 newly-registered junior college and undergraduate students in the 10 medical radiology schools in Taiwan in 2021 (Table 3). Based on the academic program, there was the highest number of newly-registered students in the undergraduate program of a general university (350, 49.65%), followed in a descending order by the undergraduate program of a technological university (235, 33.33%), and the training program of a junior college (120, 17.02%) (Table 3). Based on the school location, there was the highest number of newly-registered students in the southern (264, 37.45%) and central (262, 37.16%) regions of Taiwan, followed in a descending order by the northern region (140, 19.86%), and the eastern region (39, 5.53%).

In terms of total students with official student status, there were a total of 2923 medical radiology students in Taiwan in 2021. The number of female students (1631, 55.80%) was higher than the number of male students (1292, 44.20%). Based on academic program, the numbers of female students in the undergraduate program of a general university (782) and the training program of a junior college (403) were both higher than those of male students (518 and 174, respectively), while the number of male students in the undergraduate program of a technological university (600) was higher than the number of female students (446) (Table 3).

Based on the school location, the numbers of female students in the central (563) and southern (120) regions were higher than the corresponding numbers of male students (499 and 76, respectively), while the numbers of male students in the northern (312) and eastern (115) regions were higher than the corresponding numbers of female students (308 and 50, respectively) (Table 3).

In terms of medical radiology graduates, there were a total of 642 medical radiology graduates in Taiwan in 2021. The number of female graduates (359, 55.92%) was higher than the number of male graduates (283, 44.08%). Based on the academic program, the numbers of female graduates in the undergraduate program of a general university (193) and the training program of a junior college (55) were

Table 1 The education system of medical radiology in 10 medical radiology schools in Taiwan.

No.	University or college name	Department name	Established time of academic program				Location	Region of Taiwan
			Junior college for Associate Bachelor	Undergraduate program for Bachelor	Graduate program			
					Master	PhD		
1	Yuanpei University of Medical Technology	Department of Medical Imaging and Radiological Technology	1965 (Stopped enrolling new students in 2003)	1999	2002		Hsinchu City	Northern
2	Central Taiwan University of Science and Technology	Department of Medical Imaging and Radiological Sciences	1966 (Stopped enrolling new students in 2008)	1998	2002	2008	Taichung City	Central
3	National Yang Ming Chiao Tung University	Department of Biomedical Imaging and Radiological Sciences		1990	1998	2001	Taipei City	Northern
4	Kaohsiung Medical University	Department of Medical Imaging and Radiological Sciences		1994	2001		Kaohsiung City	Southern
5	Chang Gung University	Department of Medical Imaging and Radiological Sciences		1996	2007	2014	Taoyuan City	Northern
6	Tzu Chi University of Science and Technology	Department of Medical Imaging and Radiological Sciences	1996 (Stopped enrolling new students in 1999)	1999	2008		Hualien County	Eastern
7	I-Shou University	Department of Medical Imaging and Radiological Sciences		2002	2008		Kaohsiung City	Southern
8	Chung Shan Medical University	Department of Medical Imaging and Radiological Sciences		2002	2010		Taichung City	Central
9	China Medical University	Department of Biomedical Imaging and Radiological Science		2003	2011		Taichung City	Central
10	Shu-Zen Junior College of Medicine and Management	Department of Medical Imaging and Radiology	2004				Kaohsiung City	Southern

Table 2 The current status of dental radiology curricula in the medical radiology schools in Taiwan.

Type 1: Independent curriculum for the dental radiology					
No.	School name	School category	Course title	Compulsory/Elective	Credit
1	Yuanpei University of Medical Technology	Technological university	Dental radiology	Elective	2
2	Central Taiwan University of Science and Technology	Technological university	Dental radiography	Compulsory	1
3	Kaohsiung Medical University	General university	Technique of dental radiography	Elective	2
4	Tzu Chi University of Science and Technology	Technological university	Computed tomography and dental radiography	Elective	2
			Application of dental radiographic technique and oral health care	Elective	2
5	Shu-Zen Junior College of Medicine and Management	Technological college	Dental radiographic technology	Elective	2
Type 2: Non-independent curriculum, but the dental radiology was included in the general medical radiology curriculum					
No.	School name	School category	Course title	Compulsory/Elective	Course hours for dental radiology
1	National Yang Ming Chiao Tung University	General university	Clinical radiodiagnostic technology & clinical radiodiagnostic technology lab	Compulsory	4
2	Chang Gung University	General university	Principles and techniques of diagnostic radiology	Compulsory	2
3	I-Shou University	General university	Radiological diagnosis instrumentation	Compulsory	4
4	Chung Shan Medical University	General university	Special radiographic technology	Compulsory	4
5	China Medical University	General university	Principles and techniques of diagnostic radiology	Compulsory	4
Type 3: Dental radiology internship was included in the curriculum of diagnostic radiology internship					
No.	Internship place	Hospital qualification	Course title	Compulsory/Elective	Internship weeks (hours) ^a
1	Dental radiology department of hospital	Teaching hospital qualified by the Ministry of Health and Welfare	Diagnostic radiology internship	Compulsory	12 weeks (480 h)

^a This was the minimum number of internship weeks (hours) for diagnostic radiology internship, and the number of hours required for dental radiology internship was determined by each teaching hospital.

Table 3 The numbers (proportions) of medical radiology schools, their newly-registered students, total students with official student status and graduates by gender, school location, and academic program in 2021.

	Medical radiology schools	Newly-registered students	Total students with official student status			Graduates		
			Male	Female	Total	Male	Female	Total
Academic program								
Undergraduate program of general university	6	350 (49.65%)	782 (26.75%)	1300 (44.47%)	97 (15.11%)	193 (30.06%)	290 (45.17%)	
Undergraduate program of technological university	3	235 (33.33%)	446 (15.26%)	1046 (35.79%)	154 (23.99%)	111 (17.29%)	265 (41.28%)	
Training program of junior college	1	120 (17.02%)	403 (13.79%)	577 (19.74%)	32 (4.98%)	55 (8.57%)	87 (13.55%)	
School location in Taiwan								
Northern	3	140 (19.86%)	308 (10.54%)	620 (21.21%)	68 (10.59%)	83 (12.93%)	151 (23.52%)	
Central	3	262 (37.16%)	563 (19.26%)	1062 (36.33%)	107 (16.67%)	151 (23.52%)	258 (40.19%)	
Southern	3	264 (37.45%)	120 (4.11%)	1076 (36.81%)	76 (11.84%)	120 (18.69%)	196 (30.53%)	
Eastern	1	39 (5.53%)	50 (1.70%)	165 (5.64%)	32 (4.98%)	5 (0.78%)	37 (5.76%)	
Total	10	705 (100%)	1631 (55.80%)	2923 (100%)	283 (44.08%)	359 (55.92%)	642 (100%)	

higher than the corresponding numbers of male graduates (97 and 32, respectively), while the number of male graduates in the undergraduate program of a technological university (154) was higher than the number of female graduates (111) (Table 3). Based on the school location, the numbers of female graduates in the northern (83), central (151) and southern (120) regions were higher than the corresponding numbers of male graduates (68, 107 and 76, respectively), while the number of male graduates in the eastern regions (32) were higher than the number of female graduates (5) (Table 3).

The distribution of qualified teaching hospitals with a dental radiology department in Taiwan in 2022

According to the results of dental radiology education survey and the website of the Ministry of Health and Welfare, there were currently 53 qualified teaching hospitals (including their branches) with a dental radiology department in Taiwan (Table 4). Of these 53 qualified teaching hospitals, 21 (39.62%) were medical centers, 25 (47.17%) regional hospitals, and 7 (13.21%) district hospitals. Based on their location, 29 (54.72%) hospitals were in the northern region, 10 (18.87%) in the central region, 12 (22.64%) in the southern region, and 2 (3.77%) in the eastern region of Taiwan. It indicates that the teaching hospitals of dental radiology are mainly medical centers and regional hospitals, and these large hospitals are concentrated in the northern region of Taiwan (Table 4).

The training hours of dental radiology internship in the teaching hospitals of different hospital levels

According to the results of dental radiology education survey and the website of the Ministry of Health and Welfare, we found the 38 qualified teaching hospitals (including their branches) which offered the curriculum of dental radiology internship for medical radiology students in Taiwan (Table 5). Of these 38 qualified teaching hospitals, 18 were medical centers, 18 regional hospitals, and 2 district hospitals. Based on the number of training hours, a half (19) of the 38 hospitals which offered 40 training hours for dental radiology internship. In terms of mean training hours, medical centers offered a greater number of training hours (30.44 h) for medical radiology students, followed by the regional hospitals (28.67 h) and district hospitals (22 h), all of which showed a descending order. The mean training hours were 29.16 in overall. In terms of availability, medical centers have the highest ratio (85.71%, 18/21) of the number of qualified teaching hospitals with a dental radiology department which offered the curriculum of dental radiology internship to the total number of qualified teaching hospitals with a dental radiology department, followed by the regional hospitals (72%, 18/25) and district hospitals (28.57%, 2/7), all of them were showed in a descending order. The availability was 71.70% (38/53) in overall. It indicates that the large teaching hospitals offered more training hours for the medical radiology students and have a higher availability (Table 5).

Table 4 The numbers (proportions) of qualified teaching hospitals (including their branches) with a dental radiology department by hospital level and hospital location in Taiwan in 2022.

Hospital level	Hospital location (region of Taiwan)				Overall
	Northern	Central	Southern	Eastern	
Medical center	11 (20.75%)	4 (7.55%)	5 (9.43%)	1 (1.89%)	21 (39.62%)
Regional hospital	11 (20.75%)	6 (11.32%)	7 (13.21%)	1 (1.89%)	25 (47.17%)
District hospital	7 (13.21%)	0	0	0	7 (13.21%)
Overall	29 (54.72%)	10 (18.87%)	12 (22.64%)	2 (3.77%)	53 (100%)

Discussion

Dental radiology is an important portion for dental practice. In addition to the diagnoses of oral and dental hard tissue diseases, all the evaluation before dental treatment, the judgment during treatment, the determination of post-treatment outcomes, and the subsequent follow-up assessments must rely on the dental radiology. However, in Taiwan, the amount of dental radiology learning for both dental students and medical radiology students was too little. In this study, we found that formal medical radiology education of Taiwan started in 1965, but it stayed at the junior college level for about 25 years until the first university-level medical radiology school was established in 1990. Over the next 11 years, the medical radiology education in Taiwan had the graduate program for Master degrees in 1998 and the graduate program for PhD degrees in 2001, developing gradually into a more complete medical radiology education system. However, currently, the complete dental radiology curricula in the medical radiology schools were still scarce.

In terms of type 1 curriculum, all four medical radiology schools of technological universities or colleges offered one or two independent curricula of dental radiology for their students, while only one out of six medical radiology schools of general universities offered one independent curriculum of dental radiology (Table 2). In Taiwan, higher education is divided into two systems: general university and technological university systems. General universities mainly enroll senior high school graduates, while technological universities mainly enroll senior vocational school

graduates. Moreover, general universities usually focus on theoretical courses, while technological universities usually focus on technical courses. According to the Medical Radiation Technologists Act of Taiwan, medical radiation technologies perform the following functions: (1) general radiography for diagnostic radiology, (2) nuclear medical in-vitro examination, (3) special radiography and imaging for diagnostic radiology, (4) radiotherapy, (5) imaging and in-vivo analysis and examination for nuclear medical diagnosis, (6) nuclear medical therapy, (7) magnetic resonance imaging (MRI) and non-ionizing radiation imaging (such as ultrasound for bone mineral density test), and (8) other activities recognized by the central competent authority.¹⁰ However, dental radiology was just a small item in general radiography for diagnostic radiology. Therefore, it was understandable that most medical radiology schools did not have any independent curriculum of dental radiology for their undergraduate students. All medical radiology schools of technological universities or colleges had at least one technology-oriented independent curriculum of dental radiology, which was indeed in line with the educational policy of technological university system. However, we still considered that the current status of dental radiology curricula in the medical radiology schools in Taiwan was indeed seriously insufficient. Except for those students who had taken the independent curriculum of dental radiology, the worst-case scenario was that a medical radiology graduate received only 2 learning hours of dental radiology in the general medical radiology curriculum and only 4 training hours of dental radiology in the curriculum of diagnostic radiology internship.

Table 5 The numbers of qualified teaching hospitals (including their branches) with a dental radiology department which offered the curriculum of dental radiology internship by hospital level in Taiwan in 2022.

Hospital level	Number of qualified teaching hospitals which offered the curriculum of dental radiology internship					Overall	Mean training hours	Availability ^a
	Training hours of dental radiology internship	4–8	12–16	20–24	32			
Medical center	1	0	7	1	9	18	30.44	85.71% (18/21)
Regional hospital	1	3	5	0	9	18	28.67	72% (18/25)
District hospital	1	0	0	0	1	2	22	28.57% (2/7)
Overall	3	3	12	1	19	38	29.16	71.70% (38/53)

^a The ratio of the number of qualified teaching hospitals with a dental radiology department which offered the curriculum of dental radiology internship to the total number of qualified teaching hospitals with a dental radiology department.

Currently we do not find any independent education system and licensing system for radiation technologists with dental assistant-certified qualification in Taiwan. According to Ionizing Radiation Protection Act of Taiwan, the licensed medical radiation technologists are the only personnel who can legally operate dental X-ray equipment other than the licensed dentists. On the other hand, with the rapid advancement of dental technology, dental radiology has also developed rapidly. The work content of dental radiology for a medical radiation technologist includes operating a variety of dental X-ray equipment for taking periapical, bite-wing, occlusal, panoramic, cephalometric, temporomandibular joint (TMJ), and cone-beam computed tomography (CBCT) images.¹¹ Therefore, it is reasonable to expect the medical radiology students to have the opportunity to learn more knowledge and techniques related to dental radiology.

In terms of distribution of medical radiology students, in overall, there were more female students than male students, but in the undergraduate programs of technological universities and the only one eastern medical radiology school, there were more male students than female students (Table 3). The reasons for this gender disparity among different academic programs and school locations and its future impact on graduates' practice location choices remained to be further studied. On the other hand, we also found that it was unbalanced between the geographical distributions of medical radiology students and dental radiology internship training resources (teaching hospitals of dental radiology). Indeed, the central and southern regions had the majority of medical radiology students (more than the 70% of overall students) (Table 3), but more than half of the teaching hospitals of dental radiology were concentrated in the northern region of Taiwan (Table 4). This imbalance may cause differences in the teaching and learning qualities of dental radiology internship for medical radiology students in the different regions, which deserves us to pay more attentions. In fact, there were many large teaching hospitals concentrated in the northern region of Taiwan (Table 4).

On average, medical centers offered the more training hours (30.44 h) of dental radiology internship for medical radiology students, followed by regional hospitals (28.67 h) and district hospitals (22 h) in this study (Table 5), which showed a descending order. This reflects that northern medical radiology students are likely to get better teaching and learning qualities of dental radiology internship. Furthermore, the choppy distribution of dental sources is a long-status hassle in Taiwan.^{12–19} This issue indicates not merely the uneven distribution of dental institutions (including dental teaching hospitals), dentists, dental students, and dental education, but also the uneven distribution of other related personnel, including dental technicians, dental radiation technologists, oral hygienists, and dental nurses.

In this study, there were a total of 642 medical radiology graduates in Taiwan in 2021 (Table 3). However, the availability of dental radiology teaching hospitals was only 71.70% in 2022 (Table 5). This means that of the 53 qualified teaching hospitals with a dental radiology department, 38 offer dental radiology internship for medical radiology students, but the other 15 do not offer dental radiology

internship for medical radiology students (Table 5). There were a total of 705 newly-registered medical radiology students in 2021 (Table 3). This finding indicates that the number of medical radiology graduates may not change much in the future. Therefore, how to improve the availability of dental radiology teaching hospitals to improve the teaching and learning qualities of dental radiology internship for each medical radiology student is an urgent matter.

In Taiwan, the medical radiation technologists mainly join in diagnostic radiology, but seldom work in dental institutions for dental radiology. Although there were 10 medical radiology schools with comprehensive education system and they offered medical radiology degrees from Associate Bachelor to PhD, these 10 schools offered a little dental radiology curriculum at the undergraduate level. It means that there are few related training systems of dental radiation technologists in the medical radiology education system. Besides, Taiwan's dental schools also offered few dental radiology curricula at the undergraduate level. Hence, most licensed medical radiation technologists in Taiwan join in dental radiology with very little learning related to dental radiology during his or her student years. He or she should receive some on-the-job training before he or she can engage in his or her job, respectively. Similarly, a licensed dentist performs dental radiology, but he or she take few dental radiology curricula during his or her student days.²⁰ However, in Taiwan, dentists often work in dental clinics, yet medical radiation technologists often work in hospitals. In fact, most dentists in dental clinics do not expect medical radiation technologists to assist with the work of performing dental radiography.

Nonetheless, we consider that an education system for dental radiology needs to be established in the future, from dentistry and medical radiology perspective, including the innovative dental radiology curricula developed for medical radiology students and more dental radiology curricula designed for dental students. This in turn can create new career options for medical radiology students and new practice directions for medical radiation technologists, and then expand their potential involvement in dental radiology.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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