A preliminary study on submariners with xerostomia after a 3-month deployment

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Abstract
To observe the clinical manifestations and salivary secretion of xerostomia patients in submariners who engaged in a three-month deployment. The general conditions and clinical examination of the 136 submariners were evaluated, by which the patients with xerostomia were screened out and their clinical manifestations were recorded. Besides, the flow rate of unstimulated saliva and stimulated saliva was measured and calculated. Subsequently, the related factors of xerostomia were quantitatively classified and statistically analyzed. In all the involved submariners, 42 were diagnosed to have xerostomia by physical examination after they returned from the task, among which 71.4% showed a decrease in unstimulated salivary flow rate and it was significantly correlated with the accompanying symptoms and their general conditions. Therefore, it was concluded that the occurrence of xerostomia could be related to the service life and job responsibilities of the submariners. The main manifestations were the reduction of unstimulated salivary secretion and the accompanying clinical symptoms such as cheilosis and angular cheilitis. Noticeably, the high psychological pressure and harsh living conditions need to be concerned, and further study should place more concentrations on these comprehensive influence factors and preventive actions of xerostomia.

Abbreviation: SFR = salivary flow rate.

Keywords: salivary flow rate, submariners, xerostomia

1. Introduction
Xerostomia is an oral symptom caused by multiple factors. It is commonly manifested as salivary stickiness, dry lips, abnormal taste, burning sensation of mucosa and affected oral function such as swallowing, chewing, and pronunciation.[1, 2] Current epidemiological investigations have found that the main causes of xerostomia include salivary gland dysfunction,[3, 4] systemic diseases,[5] medication,[6] head and facial radiotherapy,[7, 8] trauma and psychosocial factors.[9–11]

It is known that the pathogenesis of xerostomia is complex, resulting in reduced salivary secretion and pH value, along with the occurrence of dry mouth, taste disorders, dental caries, periodontitis and other diseases, which can be long-term or even life-long and seriously affect the life quality of patients.[12, 13] The main and critical cause of xerostomia is the reduction of salivary secretion, and especially the unstimulated salivary flow rate (SFR) is most correlated to xerostomia. Studies have shown that when the saliva flow rate is reduced to 50% of the normal value, it will produce a feeling of dry mouth.[7]

In the present study, a special group of people employed in a specific 3-month submarine deployment was observed. The noise inside the submarine is very loud, the humidity is high and the temperature is usually over 30°C all year around. Besides, the activity space is very narrow, and the air cannot be exchanged for a long time. Therefore, the living environment inside is extremely harder than the life on land. Living in a closed environment for a long time will bring submariners severe psychological pressure. Combined with the above factors, the complex living environment often brings the changes of submariners’ oral situation, especially oral diseases such as xerostomia. Hence, the present study was aimed to observe the occurrence of xerostomia in submariners after a 3-month undersea mission. The salivary secretion of submariner patients with xerostomia after the deployment was measured, and further studied whether the reduction of salivary secretion was related to their general condition, clinical symptoms and signs. The present study may facilitate the prevention and clinical treatment for submariner patients with xerostomia, which may also lay a foundation for further exploring the related pathogenesis in this field.
2. Materials and methods

A Chinese submarine performed a three-month deployment in 2018, before when, a total of 136 submariners were undergone a physical examination. All the participated submariners had routine physical examination, including oral examination before the assignment. The selected submariners were required to be healthy males with all functional indexes in the normal range. For oral examination, the selected participants had normal salivary function without abnormal symptoms. Their ages ranged from 20 to 55 (median=35.00, Q25-Q75: 27.50–42.00), and have served for a median of 15 years (Q25-Q75: 7.50–22.00). After the mission was accomplished, 42 of the 136 participants were screened for clinical indications of xerostomia, and the subjective symptoms of xerostomia were verified. The inclusion criteria adopted Navazesh’s definition of xerostomia,[14] that is, patients had subjective feeling of xerostomia that could not be improved through normal drinking water, and patients with substantial oral mucosal lesions were excluded. In addition, the study was conducted blindly to sample collector, index analyst and statistician. The ethics committee of Affiliated Hospital of Qingdao University (China) approved this study.

2.1. Personal information

Forty-two submariners who were screened to have xerostomia after this deployment filled in personal data questionnaires, including age, position and service life (Table 1). Furthermore, their subjective symptoms and main clinical symptoms were recorded. Subjective symptoms include: patients who need to sip water from time to time are defined as “mild”; patients who need water in the mouth frequently, have unclear mouth are defined as “moderate”; patients who need water in the mouth at any time, and often have a sense of obstruction when swallowing are defined as “severe”. Clinical examinations include:

(1) Dry lips;
(2) Burn mouth;
(3) Angular cheilitis.

2.2. Salivary secretion detection

(1) Unstimulated SFR: patients fasting 2hours, no brushing and smoking. Rinse mouth with clean water, spit out and sit on the dental chair. Keep in a quiet state, lean forward slightly. First swallow the original saliva in the mouth, and then start spitting the saliva naturally secreted into a measuring cup for 5 minutes to calculate the total saliva volume and flow rate. During the test, the subject should not think about stimulating food, and swallow saliva.

(2) Stimulating SFR: After 5 minutes of unstimulated saliva collection, rinse mouth with clean water, spit out, sit on dental chair, slightly open mouth, drop 10% citric acid 3 to 4 drops on the tip of tongue, let the subject closed mouth for 5 minutes, then spit saliva slowly into a calibrated test tube. Calculate the total saliva volume and flow rate. Do not spit or swallow saliva during the test.

(3) The criteria for judging whether the unstimulated SFR and stimulated SFR decrease in 5 minutes are as follows: unstimulated SFR is less than 0.1 mL/minute, and stimulating SFR is less than 1 mL/minute, the hypofunction of salivary gland can be diagnosed as true xerostomia.

2.3. Statistical analysis

A total of 136 submariners were enrolled, in which 42 were diagnosed with xerostomia. Cases, incidence and proportion of each counting data were determined. Median and percentile range was used to describe measurement data. Spearman rank correlation test was used to analyze the correlation between SFR and status of patients (including general condition, subjective symptoms and clinical signs), and the correlation between severity of xerostomia and status of patients. Fisher exact test is used when more than 20% cells have less than 5 expected count number. Most tests can meet a power level of 70% or higher. Hypothesis testing was 2-sided with a statistical significant level of 0.05. All data were handled and analyzed using SAS version 9.3 (SAS Institute, Cary, NC).

3. Results

3.1. General information

The diagnosed 42 patients were 34.00 (Q25–Q75: 26.50–39.25) years old with service period of 14.00 (Q25–Q75: 6.50–19.25) years. Among them, only a small part was officers and operators (22 (16.18%) and 19(13.97%), respectively), and the rest were ordinary enlisted (95 (69.85%)). The morbidity rates among positions were statistically significant different ($\chi^2 = 14.659, P = .001$). However, similar morbidity performances in subgroups of different age and service period were found (Table 1).

3.2. Subjective symptoms and clinical examinations

Since 136 submariners were included in the mission, 42 (30.88%) were screened out to have got xerostomia. However, only 24 (57.14%) of them showed moderate subjective symptoms. From the clinical examination, the case number for dry lips, burning mouth and angular stomatitis were 23 (54.76%), 12 (28.57%), and 7 (16.67%), respectively. No severe dysfunction of oral function caused by xerostomia was found at the time.

There were 17 cases (40.48%) with unstimulated SFR above 0.25 mL/minute (normal). At the same time, 9 (21.43%) cases were between 0.1 and 0.25 mL/minute and 16 (38.10%) cases

| Table 1 | General Conditions of all participants (n=136). |
|---------|-----------------------------------------------|
| Group   | N (%) | Xerostomia N (%) | $\chi^2$ | P   |
| Age     |       |                 |         |     |
|          | 25    | (19.85)         | 10 (7.04) | 0.614 | .736 |
| 26–45   | 88    | (65.24)         | 25 (18.57) |      |     |
| 46+     | 23    | (16.91)         | 7 (30.43) |      |     |
| Position|       |                 |         |     |
| Officer | 22    | (16.18)         | 6 (27.27) | 14.659 | .001 |
| Enlisted| 95    | (69.85)         | 23 (24.21) |      |     |
| Operator| 19    | (14.37)         | 13 (68.42) |      |     |
| Service Life| 50 (36.76) | 21 (42.00) | 4.802 | .001 |
| ~10     | 45    | (33.09)         | 12 (26.67) |      |     |
| 11–20   | 50    | (36.76)         | 21 (42.00) |      |     |
| 21+     | 41    | (30.15)         | 9 (21.95) |      |     |
| Total   | 136   | (100.0)         | 42 (30.88) |      |     |

Spearman correlation tests are used with statistical significant level of 0.05. $P_{<.05}$.

$P_{<.01}$. 

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were below 0.1 mL/minute, respectively. The stimulated SFR above 1.0 mL/minute (normal) was 18 cases, accounting for 42.86%. At the same time, 15 (35.71%) cases were between 0.7 and 1.0 mL/minute and 9 (21.43%) cases were below 0.7 mL/minute (Table 2).

3.3. Analysis related factors for xerostomia submariners

There was a statistically significant correlation between age group and SFR (P < .05), both unstimulated SFR and stimulated SFR (Table 3). According to age grouping, patients displayed lower unstimulated and stimulated SFR level with age increasing (Table 3). Besides, patients with longer service period were more likely to show lower SFR level. Meanwhile, statistically significant correlations were also observed in clinical symptom (including cheilosis, burn mouth, and angular cheilitis) and SFR level (P < .05).

Considering the severity of xerostomia, older patients are likely to have more severe symptoms (χ² = 8.027, P = .013). The same trend was also seen in the relationship between length of service and the severity of symptoms (χ² = 7.146, P = .028). Moreover, patients who claimed dry mouth symptoms always showed a higher severity of xerostomia (Table 4).

Although longer service period often lead to higher risk of moderate subjective xerostomia symptom (χ² = 7.146, P = .029), no statistical correlation between service period and xerostomia level in enlisted patients subgroup was spotted, which suggested

### Table 2
Symptoms of patients with xerostomia (n=42).

| Symptoms          | N  | Percent (%) |
|-------------------|----|-------------|
| Subjective symptom |    |             |
| Mild              | 18 | 42.66       |
| Moderate          | 24 | 57.14       |
| Severe            | 0  | 0.00        |
| Clinical symptom  |    |             |
| Cheilosis         | 23 | 54.76       |
| Burn mouth        | 12 | 28.57       |
| Angular cheilitis | 7  | 16.67       |
| Unstimulated SFR (ml/min) |     |             |
| ~0.1              | 16 | 38.10       |
| 0.1~0.25          | 9  | 21.43       |
| 0.25~              | 17 | 40.48       |
| Stimulated SFR(ml/min) |     |             |
| 0.7~1.0           | 9  | 21.43       |
| 1.0~              | 18 | 42.66       |

SFR = salivary flow rate.

### Table 3
The correlation between level of SFR and status of patients (n=42).

| Group | General status | Stimulated SFR N (%) | Unstimulated SFR N (%) | χ² | P |
|-------|----------------|----------------------|------------------------|----|---|
|       | Age Period     | ~0.7 0.7~1.0 1.0~     | ~0.1 0.1~0.25 0.25~     |     |   |
|       | ~25            | 6 (0.9) 1 (6.7) 9 (50.0) | 1 (6.3) 0 (0.0) 9 (52.9) | 12.251 | .008† |
|       | 26~45          | 6 (66.7) 11 (73.3) 8 (44.4) | 12 (75.0) 5 (55.6) 8 (47.1) | 7.200 | .099 |
|       | 46~            | 3 (33.3) 3 (20.0) 1 (5.6) | 3 (18.8) 4 (44.4) 0 (0.0) | 16.631 | .001 † |
|       | Serve Period   | No                   | 12 (28.6)              | 16.631 | .001 † |
|       | ~10            | 1 (11.1) 2 (13.3) 9 (50.0) | 2 (12.5) 1 (11.1) 9 (52.9) | 14 (43.8) | .008† |
|       | 11~20          | 5 (55.6) 10 (66.7) 6 (33.3) | 11 (68.8) 4 (44.4) 6 (35.3) | 16.631 | .001 † |
|       | 21~            | 3 (33.3) 3 (20.0) 1 (5.6) | 3 (18.8) 4 (44.4) 2 (11.8) | 16.631 | .001 † |
|       | Clinical symptom| Cheilosis 8 (88.9) 13 (86.7) 2 (11.1) | 8 (87.5) 7 (77.8) 2 (11.1) | .0001† |
|       | Burn mouth     | 5 (55.6) 6 (40.0) 1 (5.6) | 5 (55.6) 6 (40.0) 1 (5.6) | 9.208 | .008† |
|       | Angular cheilitis | 6 (66.7) 1 (6.7) 0 (0.0) | 7 (43.8) 0 (0.0) 7 (43.8) | 16.158 | .001† |

Fisher Exact Spearman correlation tests are used with statistical significant level of 0.05.
† P < .05.
* P < .01.
SFR = salivary flow rate.

### Table 4
The correlation between the severity of Xerostomia and status of patients (n=42).

| Group | Xerostomia level | Moderate N (%) | χ² | P |
|-------|------------------|----------------|----|---|
| Age   | ~25              | 8 (44.44) 2 (8.33) | 16.631 | .001 † |
|       | 26~45            | 9 (50.00) 16 (66.67) | 7.146 | .028† |
|       | 46~              | 1 (5.56) 6 (25.00) | 3.368 | .064 |
| Position | Officer       | 1 (5.56) 5 (20.83) | 13.463 | .001† |
|       | Enlisted        | 13 (72.22) 10 (41.67) | 7.146 | .028† |
|       | Operator        | 4 (22.22) 9 (37.50) | 3.939 | .142 |
| Service Life | ~10         | 9 (50.00) 3 (12.50) | 3.939 | .142 |
|       | 11~20           | 6 (33.33) 15 (62.50) | 3.939 | .142 |
|       | 21~             | 3 (16.67) 6 (25.00) | 3.939 | .142 |
| Clinical symptom | Cheilosis 4 (9.9) 19 (43.8) | 13.463 | .001† |
|       | Burn mouth      | 2 (5.1) 10 (23.8) | 4.706 | .042* |
|       | Angular cheilitis | 0 (0.00) 7 (16.7) | 6.300 | .001* |

* Fisher Exact Test used when the more than 20% cells have expected count less than 5.
that to certain extent patients with longer service period were more prone to have xerostomia, and position assignment may be an unavoidable factor that affects radiation exposure (Table 4). Besides, Table 5 revealed that cheilosis was the most commonly seen symptom compared with other 2 clinical symptoms. Although same occurrence happened in age group of 21∼25, only burn mouth occurrence statistically significantly correlated with service period ($\chi^2=9.053$, $P=.006$). Compared with stimulated SFR level, a statistically significant relationship was discovered between service period and unstimulated SFR ($\chi^2=9.573$, $P=.038$). Besides, a similar decline trend was also found in stimulated SFR levels. Likewise, it was clearly displayed that the degree of xerostomia had positive correlation with service life and their ages (Fig. 1).

### Table 5
The correlation of symptoms among different service periods.

| Group                     | Service Period (n=42) N (%) | Enlisted service period (n=23) N (%) | $\chi^2$ | $P$ |
|---------------------------|-----------------------------|-------------------------------------|----------|-----|
|                          | −10 | 11−20 | 21− | −10 | 11−20 | 21− | $\chi^2$ | $P$ |
| Subjective symptom        |     |       |     |     |       |     |          |     |
| Mild                      | 9 (75.0) | 6 (28.6) | 3 (33.3) | 8 (80.0) | 3 (30.0) | 2 (66.7) | 7.146 | .029$^*$ |
| Moderate                  | 3 (25.0) | 15 (71.4) | 6 (66.7) | 2 (20.0) | 7 (70.0) | 1 (33.3) |      |     |
| Stimulated SFR 0−0.7      | 1 (8.3) | 5 (23.8) | 3 (33.3) | 0 (0.0) | 1 (10.0) | 1 (33.3) | 7.200 | .116 |
| 0.7−1.0                   | 2 (16.7) | 10 (47.6) | 3 (33.3) | 2 (20.0) | 6 (60.0) | 0 (0.0) |      |     |
| 1.0−                      | 9 (75.0) | 6 (28.6) | 3 (33.3) | 8 (80.0) | 3 (30.0) | 2 (66.7) | 7.886 | .054 |
| Unstimulated SFR 0−0.1    |     |       |           | 1 (10.0) | 6 (60.0) | 1 (33.3) | 6.500 | .104 |
| 0.1−0.25                  | 1 (8.3) | 4 (19.0) | 4 (44.4) | 1 (10.0) | 1 (10.0) | 0 (0.0) |      |     |
| 0.25−                     | 9 (75.0) | 6 (28.6) | 2 (22.2) | 8 (80.0) | 3 (30.0) | 2 (66.7) |      |     |
| Clinical symptom          |     |       |           |           |           |     |          |     |
| Cheilosis                 | 4 (33.3) | 13 (61.9) | 6 (66.7) | 3.059 | .223 |
| Burn mouth                | 0 (0.0) | 10 (47.6) | 2 (22.2) | 9.053 | .006$^*$ |
| Angular cheilitis         | 1 (8.3) | 3 (14.3) | 3 (33.3) | 2.287 | .365 |

Fisher’s Exact Test are used when more than 20% cells have expected count less than 5, and others are Spearman correlation tests. 0.05 is regarded as statistical significant level.$^*$ $P<.05.$

4. Discussions

The work recruited 136 submariners for examination after a 3-month deployment, of which most were 26 to 45 years old. Although the xerostomia incidences were different in the three age groups, there was no significant difference according to the age distributions, which was similar in groups classified by service time. However, the incidences displayed radical differences according to their positions. In the position-classified group, the highest incidence happened to the operators, which was probably because this group had more contacts to the nuclear fusion reactors.

Forty-two out of 136 submariners during this task were detected to have xerostomia. Fortunately, all these 42 patients...
had no severe symptoms, with 18 mild and 24 moderates, respectively. Although there was no significant difference, it was found that in this observational study, patients who have been in service for less than 10 years usually showed mild symptoms, while patients who have been in service for more than 10 years had a high occurrence of moderate symptoms. From clinical symptoms, we can see that most of them reported dry lips, some reported burning mouth, and only a few reported angular cheilitis. Dry lips are the most commonly symptoms of xerostomia.[13,14] According to the SFR, 30 patients had a decrease in unstimulated SFR, accounting for 71.4%. However, the rest 28.6% patients still have dry mouth under normal salivary secretion, which may be caused by abnormal subjective sensation or changes in salivary composition.

It is known that about 1 mL saliva was produced every minute, while saliva produced by parotid gland accounted for 20% to 25% of saliva secretion, submandibular gland and sublingual gland accounted for 70% to 75%, and other minor glands accounted for very small amounts. It indicates that xerostomia is closely related to unstimulated total saliva volume. The reduction of unstimulated saliva flow rate is the main manifestation of xerostomia.[17]

The unstimulated SFR of 42 patients with xerostomia was measured. The results showed that the reduction of unstimulated saliva had significant correlation with all the general condition of the patients, as well as the clinical symptoms. While it was the similar as for stimulated SFR. Therefore, it is more convincing that both the service time and the service period were correlated with unstimulated SFR. The longer their service life and service period, the incidence for individuals to have xerostomia was higher. Besides, with regard to the service period, it is very complex and affected by many factors, like age and positions and other general conditions. Further study should put more efforts on the analysis of these diverse factors that may cause xerostomia.

Noticeably, both unstimulated and stimulated saliva flow rate were correlated with clinical symptoms, which meant that the less saliva volume, the greater oral impact. It was learnt that the reduction of salivary secretion may be related to radiation-induced salivary gland dysfunction or functional damage, as well as the submarine’s living environment, the change of oral environment caused by air environment and the increase of psychological pressure. Therefore, the change of saliva flow rate was likely caused by comprehensive factors. There are still some limitations in the present study. Since this investigation was about a special service group, the sample size was unable to change and the obtained experimental data was restricted. Therefore, the selection bias occurred inevitably, and the statistical analysis and evaluation in certain perspectives were limited. Besides, our study on prevention actions are still under exploration, and future work will focus more on the prevention measures and related estimation.

5. Conclusions

The incidence of xerostomia in this specific task could be related to the general conditions of the submariners. Their main manifestations were the reduction of unstimulated salivary secretion and associated clinical symptoms, which were correlated with the length of service life. However, the reduction of salivary secretion may also be related to comprehensive factors such as the change of oral environment and the increased psychological pressure caused by the living and air environ-

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