Motion Sickness Induces Intestinal Transit Increase in Mice

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Motion sickness in rodents could be induced with vestibular stimulation from rotation [1]. However, rats and mice could not nauseate and vomit due to the powerful barrier between the stomach and the esophagus [2]. Instead, they exhibit pica behavior (eating of kaolin), which has already been thought as an alternative to nausea and vomiting in rats [3]. Nonetheless, no significant increase in kaolin consumption after rotation was observed in mice [4,5]. We speculated that the amount of kaolin consumption induced by rotation is too little to distinguish from that due to the curious habit in mice. Furthermore, the biological basis of pica induced by motion sickness in rodents is still unknown.

Recently, motion sickness index (MSI), fecal-based evaluation criteria, was verified to be suitable for evaluating the severity of motion sickness in mice [4,6]. The results indicated that intestinal transit may increase when mice suffer from motion sickness. On the other hand, it was demonstrated that space motion sickness could result in gastric stasis in astronauts [7]. How to clarify this conflict? We presume that the gastric stasis does exist in mice after rotary stimulus, and then, the intestinal transit is increased to resist gastric stasis instead of emesis. Moreover, in our previous study, we found that fecal granules determined MSI score to a great extent. Therefore, there may be a correlation between intestinal transit and MSI. The present work was therefore designed to investigate intestinal transit variation during motion sickness and the correlation between intestinal transit and MSI in mice.

C57BL/6J male mice weighing 18–22 g were purchased from SLRC Laboratory Animal Ltd (Shanghai, China). All animals received humane care, and experimental procedures were in com-

pliance with institutional animal care guidelines. Motion sickness was induced by biaxial rotary stimulus with 360°/s peak velocity and 20°/s² angular accelerative rotation for 40 min. MSI was calculated on the basis of a set of evaluation criteria previously published [4]. Kaolin consumption in 24 h prerotation or postrotation was recorded. Small intestinal transit and colonic transit activity were determined using 10% wood charcoal mixing 5% gum arabic as tracer dye. The ratio of distance from pylorus to the end of tracer dye and distance from pylorus to cecum was identified as small intestinal transit activity. The ratio of distance from ileocecal junction to the end of tracer dye to total length of colon was identified as colonic transit activity [8]. Data are expressed as mean ± SD. Comparisons of parameters among two groups were made by the unpaired Student's *t*-test. Data involving more than two groups were assessed by analysis of variance (ANOVA). Statistical significance was set at *P* < 0.05.

Liu et al. [9] reported mice ate a small amount of kaolin in normal condition (<0.2 g each day). In our experiment, kaolin consumption before and after rotary stimulus was 0.35 ± 0.61 and 0.38 ± 0.54 g in 24 h, respectively. Moreover, among 42 mice, 57.1% showed increased kaolin consumption after rotary stimulus. Inversely, 42.9% exhibited decreased kaolin consumption. Taken together, the results indicated that the basic consumption of kaolin is little, and the variability of kaolin consumption is huge in mice. Our results showed that pica is not suitable to evaluate the severity of motion sickness in mice.

In normal condition, the intestinal transit was increased with time after intragastric administration of tracer dye (data not

Figure 1 Display (A) and statistics (B) of small intestinal transit after different time rotary stimulus. Display (C) and statistics (D) of colonic transit after rotation. Red triangles point out the end of tracer dye. Each value represents mean $\pm$ SD ($n = 6$ in each group). $**P < 0.01$ versus control or as indicated.

shown). However, the intestinal transit showed no difference after 10- or 20-min rotary stimulus. Compared with 10- or 20-min rotation, the intestinal transit increased dramatically when treated with 40-min rotation (Figure 1A,B). These results indicated that small intestinal transit may be delayed at the early stage of rotary stimulus and increased at the late stage of rotary stimulus. The increased small intestinal transit could result in colonic transit accelerating [10]. As expected, the colonic transit was increased after 40-min rotation (Figure 1C,D).

This study showed that the small intestinal transit was positively correlated with MSI ($R = 0.447$, $P < 0.001$; Figure 2A). The small intestinal transit was negatively correlated with stomach contents ($R = -0.281$, $P < 0.001$; Figure 2B). Our previous study demonstrated that MSI can reflect the severity of motion sickness in mice [6]. So, we believed that the increase in intestinal transit may also reflect the degree of motion sickness in mice. Vomiting could help to release gastric retention when people experience motion sickness. Interestingly, mice may use the increasing intestinal transit to reduce stomach contents instead of emesis for releasing malaise.

In summary, the present work demonstrated that the small intestinal transit was delayed and then accelerated in the process of motion sickness. The increasing small intestinal transit may reflect the degree of motion sickness in mice. The increasing small

Figure 2 The small intestinal transit was positively correlated with motion sickness index (MSI) (A) and negatively correlated with stomach contents (B). $n = 29$.

intestinal transit (variant “emesis”) may be an adaptation to motion sickness in mice. In addition, small intestinal transit could be a supplement of MSI in evaluating the severity of motion sickness in mice.

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Conflict of Interest

The authors declare no conflict of interest.

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