

The impact of asynchronous online anatomy teaching and smaller learning groups in the anatomy laboratory on medical students' performance during the Covid-19 pandemic

Ming-Fong Chang¹  | Meng-Lin Liao¹  | June-Horng Lue¹ | Chi-Chuan Yeh² 

¹Department of Anatomy and Cell Biology, National Taiwan University College of Medicine, Taipei, Taiwan

²Department of Surgery, National Taiwan University Hospital, National Taiwan University College of Medicine, Taipei, Taiwan

Correspondence

Dr. Chi-Chuan Yeh, Department of Surgery, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 10617, Taiwan (R.O.C.) or National Taiwan University Hospital, National Taiwan University College of Medicine (NTUCM), No. 7, Chung Shan S. Rd. (Zhongshan S. Rd.), Zhongzheng Dist., Taipei City 100225, Taiwan (R.O.C.).
Email: anneyeh@gmail.com

Funding information

Ministry of Education, Grant/Award Number: PMN1100547; Ministry of Science and Technology, Taiwan, Grant/Award Number: MOST 109-2511-H-002-020; Ministry of Science and Technology, Grant/Award Number: MOST 110-2511-H-002-020-MY3

Abstract

Due to the Covid-19 pandemic, National Taiwan University anatomy teachers adopted asynchronous online video teaching and reduced the size of anatomy laboratory groups in April 2020. The aim of this study was to investigate the impact of these changes on medical students' learning. Before Covid-19, the performance of the 2019–2020 cohort was significantly better than that of the 2018–2019 cohort. However, the implementation of modified teaching strategies significantly lowered the laboratory midterm score of the 2019–2020 cohort in the second semester. Conversely, the final laboratory examination score of the 2019–2020 cohort was significantly higher than that of the 2018–2019 cohort. Through correlation analysis, lecture and laboratory examination scores were highly correlated. Additionally, the difference in lecture and laboratory z-scores between two cohorts, the Likert scale survey and free-text feedback of the 2019–2020 cohort, were conducted to show the impact of modified teaching strategies. There were several important findings in this study. First, the change in teaching strategies may temporarily negatively influence medical students to learn anatomy. Besides, analyzing the performance of laboratory assessments could be a complementary strategy to evaluate online assessments. Applying lecture examination scores to predict laboratory performance was a feasible way to identify students who may have difficulty in learning practical dissection. Finally, reducing group size together with reduced peer discussion may have a negative effect on learning cadaver dissection for students with low academic performance. These findings should be taken into consideration when anatomy teachers apply new teaching strategies in anatomy courses.

KEYWORDS

anatomy, cadaveric dissection, Covid-19, gross anatomy education, medical education, students' perceptions, TBL, Team-based learning

INTRODUCTION

Human anatomy is fundamental knowledge for medical students. Anatomy courses of medical students usually include comprehensive lectures in lecture halls and complete dissection of human

bodies in laboratories (Gangata et al., 2010; Akinola, 2011). In particular, “hands-on” dissection experience is important for medical students preparing to become surgeons to acquire surgical skills for future clinical practice (O'Leary et al., 2019; Li et al., 2020; Kim et al., 2021a). The first Covid-19 case in Taiwan was reported in January

2020, and learning practices had to be altered to follow Taiwan Centers for Disease Control guidelines (<60 people in a laboratory and a requirement to wear a mask) during the Covid-19 pandemic (Liu et al., 2020; Cheng & Huang, 2021). Inevitable changes in teaching anatomy were reported to have influence on medical students' learning during the Covid-19 pandemic (Evans et al., 2020; Pather et al., 2020; Cheng et al., 2021). Therefore, medical students in Taiwan may also be affected in learning anatomy with the implementation of modified teaching strategies under the constrictions of the Covid-19 pandemic.

Many universities adopted remote learning and online education to teach anatomy to medical students during the Covid-19 pandemic (Franchi, 2020; Longhurst et al., 2020; Pather, et al., 2020; Srinivasan, 2020). Blended learning, comprised of online and traditional teaching, could result in better student outcomes than traditional face-to-face teaching in gross anatomy courses (Pyatt & Sims, 2012; Green et al., 2018; Barash et al., 2021; Harrell et al., 2021; Zarcone & Saverino, 2022). However, replacing traditional gross anatomy teaching with completely remote learning remains controversial due to the lack of interpersonal interaction (Gillett-Swan, 2017; Pather, et al., 2020). Therefore, third-year medical students at National Taiwan University (NTU) at the onset of the Covid-19 pandemic in 2020 who experienced traditional lecture learning and remote online learning in anatomy courses provided an opportunity to evaluate the pros and cons between traditional and online learning in anatomy education.

The Covid-19 pandemic influenced not only teaching and learning, but also assessments of gross anatomy (Elzainy et al., 2020). Previous studies documented an academic integrity issue regarding online anatomy lecture assessments, such as cheating (Ikram & Rabbani, 2021; Meulmeester et al., 2021). Therefore, anatomy teachers require another academic performance index to validate the results of online lecture assessment. Fortunately, at the NTU, conventional strategies of anatomy lecture and laboratory assessments were able to maintain proper social distancing to meet the Taiwan Centers for Disease Control guidelines during the pandemic (Cheng & Huang, 2021), so both anatomy assessments in the 2018–2019 and 2019–2020 academic years were performed in the same way. Hence, analyzing the correlation between the results of laboratory and lecture assessments may provide a complementary evaluation of online lecture assessments of medical students during Covid-19.

Anatomy courses for medical students usually comprise didactic lectures and laboratory cadaver dissections. The schedules of lecture and laboratory courses vary from school to school, and there are two main types: (1) cadaver dissection is related to the content of each lecture (Holland et al., 2021; Koop et al., 2021); and (2) cadaver dissection only begins following the delivery of the entire lecture series (Huynh et al., 2021). In Taiwan, these two arrangements are applied at different medical schools. For example, the School of Medicine at NTU and post-baccalaureate medicine at Kaohsiung Medical University apply the former schedule, while the School of Medicine at National Yang-Ming Chiao-Tung University and I-Shou

University use the latter method. No matter the type, anatomy lecture courses are given before practical dissection. Therefore, students' laboratory academic performance may be predicted by their anatomy lecture examination scores.

Medical students were divided into several groups (14–15 students in each group) for dissecting cadavers and peer discussion during the dissection class prior to the Covid-19 pandemic. Hence, the anatomy learning method at the NTU is similar to team-based learning (TBL) (Chang et al., 2019). According to previous studies, peer interaction is important in TBL and flipped classroom teaching strategies (Vasan et al., 2011; Cheng et al., 2017; Sultan, 2018). Also, peer-assisted learning in a dissection course was reported to help students understand and retain anatomical knowledge and have better academic performance (Han et al., 2015). Nevertheless, the Covid-19 pandemic disrupted medical students' access to the dissection room (Franchi, 2020; Pather, et al., 2020). A recent study reported that loss of access to cadaver dissection decreased students' academic performance in learning anatomy (Tucker & Anderson, 2021). To avoid this issue at the NTU, we divided the laboratory groups into many smaller groups (four students in each group) to preserve practical cadaver dissection and to meet the restriction of <60 individuals allowed in the laboratory at one time. Therefore, students in 2019–2020 at the NTU may have encountered reduced peer discussion due to smaller group size during cadaver dissection.

The size of the dissection group is dependent on many factors, such as student number and cadaver availability. According to previous studies, group sizes ranged from 4 to 75 students per group and were mostly 6–8 students per group (Bentley & Hill, 2009; Evans & Cuffe, 2009; Han, et al., 2015; Nwachukwu et al., 2015; Rowland & Joy, 2015; Burgess et al., 2016). The optimal TBL group size has been reported to be about 5–7 members per group, and team size was suggested to be a predictor of team performance (Thompson et al., 2015). However, few studies have discussed the effect of group size on learning anatomy laboratory dissection. In addition, several disadvantages of TBL have been documented: a few students did all the work, team members did not listen to individual opinions, and high-functioning individuals competed for alpha rank within a team, which diminished team cohesion in medical education (Swaab et al., 2014; Thompson, et al., 2015; Khansari & Coyne, 2018). Additionally, a previous report indicated that some students may not cooperate with other team members very well in TBL (Thompson, et al., 2015). Therefore, feedback from NTU medical students from the 2019–2020 academic year, who experienced both larger and smaller group sizes, may provide a clue to understand the effect of different group sizes on anatomy education.

In this report, the anatomy academic performance of two cohorts of third-year medical students from 2018–2019 and 2019–2020 and the medical students' perception in the 2019–2020 cohort were collected to explore the influence of modified teaching strategies on anatomy learning during the Covid-19 pandemic. These themes were investigated by analyzing examination scores with different strategies. A Likert scale survey and free-text feedback via questionnaire were used to explore (1) the influence of remote learning on

dissection guide and practical dissection learning in the laboratory; (2) the impact of dividing laboratory groups into smaller groups on learning cadaver dissection; (3) the feasibility of accessory strategies to evaluate the lecture academic performance of medical students; and (4) the prediction of low-performing students on laboratory via lecture assessments.

MATERIALS AND METHODS

The gross anatomy course at the National Taiwan University before Covid-19

The academic year at NTU was divided into two semesters: September to January and February to June. Third-year medical students studied gross anatomy over two semesters in one academic year. The gross anatomy course included systematic anatomy, which introduces an overview of the skeletal, muscular, cardiovascular, and nervous systems from September to November. In each academic year, about 150–160 medical students learned anatomy at lecture courses in a big classroom without assigned seats, and they divided themselves into 11 groups for the anatomy laboratory course (14–15 students/group). Systematic anatomy was allocated as 22 hours for lecture courses and 22 hours for laboratory courses. After each lecture unit, the students had laboratory courses in which they were taught systematic anatomical structures by studying the general anatomy term lists organized by the anatomy teachers via human skeleton specimens and plastic human models. After completing the course, the students took the first semester midterm test to assess their understanding of the basic structures of the human body.

The first semester midterm test included both the systematic anatomy lecture and laboratory examinations. To separate each student by 1–2 empty seats, the students were arranged in 2–3 classrooms for the lecture examination. The question types of this examination included simple multiple-choice questions and matching questions. The total number of lecture questions was about 50–60, depending on the anatomy teachers. The questions of the systematic anatomy laboratory examination were to label a skeleton specimen and plastic human models, and there were 34 laboratory questions. Each student was instructed to remain 1.5–5 meters away from the next student. Each student completed the system anatomy laboratory examination from the first station to the last, and they spent 30 seconds at each station.

After the first semester midterm test, the students began to study regional anatomy, which included lectures and cadaver dissection at the laboratory from November to June. Regional anatomy was allocated into 78 hours for lecture courses and 135 hours for laboratory dissection. Each group of medical students (based on the number of students, about 14–15 per group) had a cadaver for dissection (in total, 11 cadavers were used). At the beginning of the cadaver dissection, the students learned how to manipulate surgical instruments and visited the family of their “silent teacher” to show their appreciation and learn medical humanity. The comprehensive

regional anatomy lectures introduced 15 body regions: the upper limbs, thorax, abdomen, pelvis, perineum, neck, face, back, cranial cavity, orbit, infratemporal region, pharynx, larynx, oral cavity, ear, and lower limbs (Figure 1A). Each anatomical region was allocated 2–8 hours for delivering lectures and 20–60 minutes for guiding the dissection in the classroom and 2–10 hours for practical dissection in the laboratory. To ensure every student had the same opportunity for dissection, each group arranged a rotating roster, including 4–6 students as operators and the others as observers. In this way, all students took turns performing the dissection. About 10–15 minutes before the end of each dissection, the anatomy teachers suggested that each group conducted a peer discussion to review the dissection procedures, identifying the features and depth of anatomical structures and recognizing the paths of specific nerves, vessels, and muscles. During the peer discussion, the operating students and observing students could exchange dissection and observational information. Reviews were regularly arranged until the change in teaching strategy after Covid-19. Assessments of regional anatomy included the first semester final examination, the second semester midterm, and the second semester final examination. The regional anatomy examination also consisted of lecture and laboratory examinations. The question types of the regional anatomy lecture assessment included simple multiple-choice questions, fill in the blank questions, and matching questions. The total number of lecture questions was about 60–80, which depended on the anatomy teachers. The seating arrangement for regional lecture examinations was the same as that for the systematic lecture examinations. The regional laboratory examinations were carried out in a similar way as the systematic laboratory examinations, except that the questions were prepared on whole cadavers or organs from cadavers without images, and the total number of questions was about 34 (Figure S1). The lecture and laboratory questions of the final examinations were not cumulative with the contents of the midterm assessment.

Modified teaching strategy during Covid-19

National Taiwan University announced rules for teaching during the Covid-19 pandemic, and the anatomy teachers adopted alternative strategies to avoid having too many students (< 60 persons and required mask wearing) in the classroom or laboratory at the same time. The modified strategies for the regional anatomy lectures, the dissection guide lectures, and the laboratory cadaver dissections included: (1) asynchronous online videos to replace face-to-face regional lecture teaching in the classroom; (2) asynchronous online videos to introduce the dissection guide before dissection; (3) dividing each team into smaller groups (four students in each group were operators) and setting a rotating roster, wherein each smaller group had 2 hours for laboratory dissection without observers to give every student an equal opportunity for hands-on cadaver dissection; and (4) the original time for teaching the regional anatomy lecture courses and the dissection guide lecture courses were re-allocated as regional anatomy laboratory

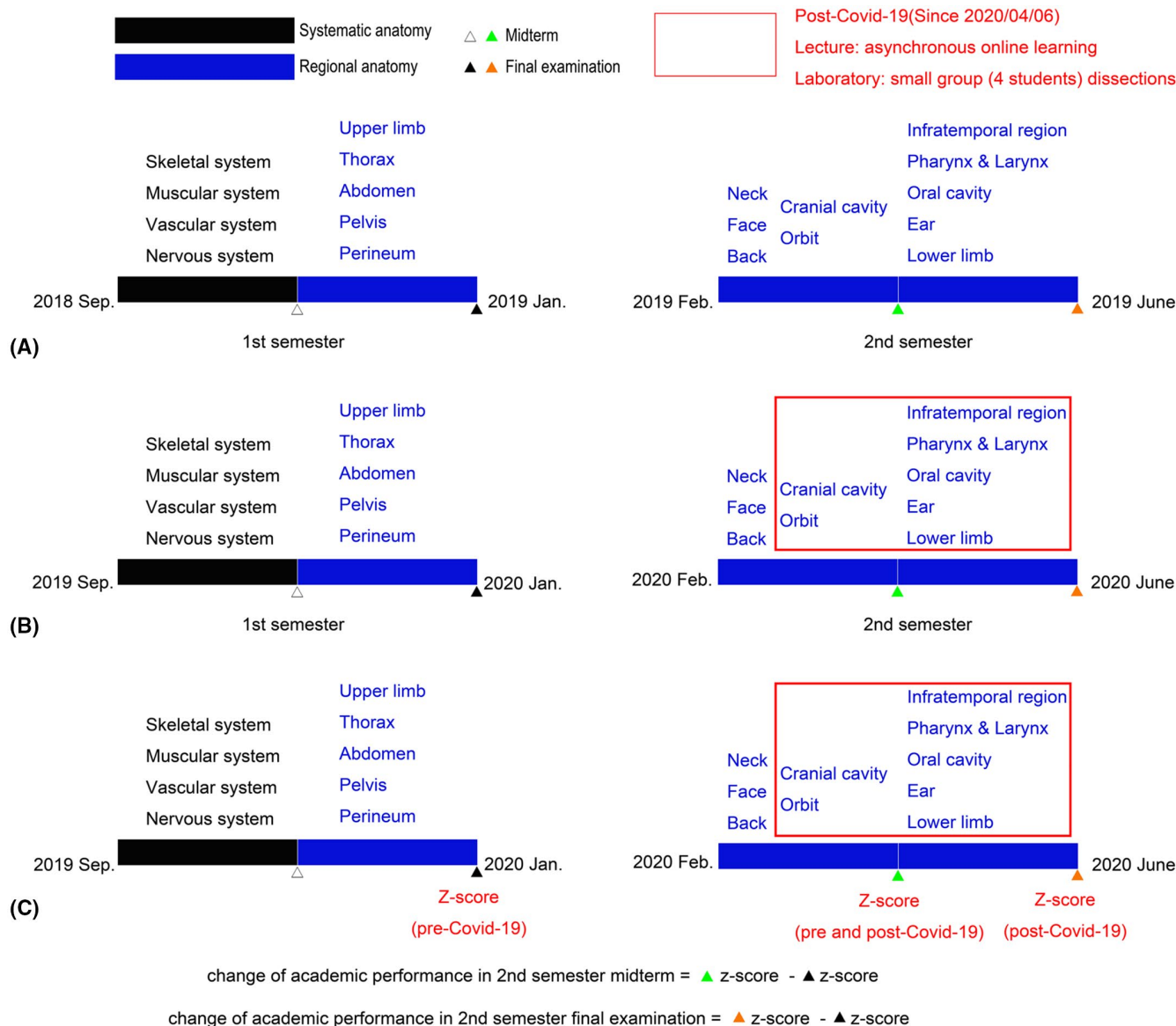


FIGURE 1 Schema of the gross anatomy course in the 2018–2019 and 2019–2020 academic years. The gross anatomy course for third-year medical students at National Taiwan University consists of units on systematic anatomy (black bar) and regional anatomy (blue bar). The midterm of the first semester (white triangle) evaluated the students' academic performance in systematic anatomy. The final examination of the first semester (black triangle) evaluated the students' academic performance on upper limb, thorax, abdomen, pelvis, and perineum regional anatomy. The midterm of the second semester (green triangle) evaluated the students' academic performance on neck, face, back, cranial cavity, and orbit regional anatomy. The final examination of the second semester (orange triangle) evaluated the students' academic performance on infratemporal region, pharynx and larynx, oral cavity, ear, and lower limb regional anatomy. The modified teaching strategies (red frame) were implemented from April 6, 2020 to the end of the second semester. The assessment strategy was the same in the two cohorts. (A) In the 2018–2019 academic year, anatomy courses were delivered by traditional teaching; (B) In the 2019–2020 academic year, anatomy courses were taught by traditional teaching and modified teaching; (C) The difference in z-score represented the change of academic performance from pre-Covid-19 to post-Covid-19

time. The students who did not participate in the dissection were instructed to review the regional anatomy lecture, the dissection guide lecture, and Grant's dissection videos (*Grant's Dissector Watch & Learn Videos*) provided with *Grant's Dissector* (Detton, 2016, 2020) via asynchronous online platform. These modified strategies began on April 6, 2020 and continued until the end of the second semester of the 2019–2020 course (Figure 1B). The medical students in the 2019–2020 cohort experienced traditional

anatomy teaching in systematic anatomy and regional anatomy from the upper limbs to the back. From April 6, 2020, medical students in the 2019–2020 cohort learned regional anatomy from the cranial cavity to the lower limbs via these modified strategies. The process of the regional lecture and the laboratory examinations in the 2018–2019 and 2019–2020 cohorts was the same even after Covid-19. The only difference between the two cohorts was that everyone had to wear masks in the 2019–2020 cohort.

Analysis of the academic performance of the 2018–2019 and 2019–2020 cohorts

Because there was no difference in the teaching strategy of systematic anatomy between the 2018–2019 and 2019–2020 cohorts, and the curriculum of systematic anatomy was different from that of regional anatomy, the authors collected the scores of the regional anatomy examination including the final examination score of the first semester and the midterm and final examination scores of the second semester of the 2018–2019 cohort ($n = 150$, third-year students, 20–24 years old, male/female ratio = 2.65) and the 2019–2020 cohort ($n = 156$, third-year students, 20–24 years old, male/female ratio = 2.62) to evaluate the influence of these modified teaching strategies during the Covid-19 pandemic on academic performance in learning regional anatomy. Because the regions covered in each examination were different, z-scores were used to elucidate the students' academic performance in learning anatomy to avoid any bias between different examinations (Ruijsbroek et al., 2015; Simmerman et al., 2018). The difference in z-score was documented to measure the change in each student's academic performance in each cohort (Coelho et al., 2019). Therefore, the change in academic performance was evaluated by the difference in z-score between the pre-Covid-19 and post-Covid-19 examinations (Figure 1C). The z-score of the final examination of the first semester (the first regional examination) for individual students was used as the baseline academic performance pre-Covid-19. The difference in the z-score of academic performance was defined as the z-score of the midterm (pre-Covid-19 and post-Covid-19) and the final examination (post-Covid-19) of the second semester minus the baseline z-score (pre-Covid-19). The difference in z-score represented either improved (a positive value) or decreased (a negative value) academic performance from pre-Covid-19 to post-Covid-19. Then, according to the standard used by the College Entrance Examination Center in Taiwan, students in the two cohorts were divided into six groups based on their final examination scores from the first semester. The subgroups were highest group (score $\geq 88\%$), upper first quartile group ($88\% > \text{score} \geq 75\%$), upper median group ($75\% > \text{score} \geq 50\%$), lower median group ($50\% > \text{score} \geq 25\%$), lower third quartile group ($25\% > \text{score} \geq 12\%$), and lowest group (score $< 12\%$). The data on the examination scores and the difference in z-scores were described as mean \pm standard deviation (SD) and were analyzed using student's *t*-test and Cohen's *d* to measure the statistical significance and effect size, respectively.

The methodology of qualitative evaluation

To understand the students' perception of the change in teaching strategy after Covid-19, an anonymous questionnaire (Table S1) was designed in three parts, including: (1) the student's grades in two semesters of gross anatomy; (2) a ten-point Likert scale survey for qualitative analysis of the teaching changes; and (3) free text for students to describe their opinions about the teaching changes and

the benefits of peer discussion. The reason for including the students' grade points was to explore differences in the Likert scale responses and comments about the teaching change between the six academic performance subgroups. All questions were designed by the anatomy teachers (M.F.C., M.L.L.) and verified by the medical educator (C.C.Y.)

To avoid the effect of the power of teacher's authority, teaching assistants invited students in the 2019–2020 cohort to fill in the anonymous questionnaire in the next semester (the first semester of the 2020–2021 academic year) at the end of the second semester of the 2019–2020 academic year. Furthermore, to increase the willingness of medical students to participate in this study, each student who completed the questionnaire was compensated with USD \$8.00. As a result, 98 medical students participated in the questionnaire investigation. This study was ethically approved by the Research Ethics Committee of the National Taiwan University.

The ten-point Likert scale survey in the second part of the questionnaire was designed to quantitate students' agreement on four topics: (1) the change in teaching the anatomical dissection guide via asynchronous online learning; (2) small groups for anatomical dissection; (3) rotating practical dissection at different times; and (4) the influence of losing peer discussion. All questions were designed by the anatomy teachers (M.F.C., M.L.L.) and verified by the medical educator supervisor (C.C.Y.).

The analysis of the ten-point Likert scale survey was presented via a horizontal bar graph, and the Cronbach's alpha test was conducted to measure the reliability of the survey. The Likert scale scores were analyzed using student's *t*-test and Cohen's *d* to measure the statistical significance and effect size, respectively. All statistical analyses were conducted using SPSS statistical package, version 26 (IBM Corp., Armonk, NY), Prism 6 software (GraphPad Software Inc., San Diego, CA), and RStudio desktop application (RStudio Inc., Boston, MA). The statistical significance was set at $P < 0.05$.

The qualitative survey of free-text feedback from students was conducted to thematically ascertain the students' perception of the modified teaching strategies during the Covid-19 pandemic (Table S2). Three issues were selected to investigate students' perceptions: (1) the perception of asynchronous online learning was ascertained with the question: "What do you think about replacing traditional face-to-face teaching with an asynchronous online video for the laboratory dissection guide?"; (2) the perception of dividing laboratory groups into smaller ones in learning cadaver dissection was ascertained with the question: "What do you think about medical students being grouped into many smaller groups (four students per group) to conduct dissection at different times?"; and (3) the perception of lacking peer discussion due to the smaller group size was ascertained with the question: "What do you think about peer discussion being necessary and beneficial for learning cadaver dissection?" The students were encouraged to write down comments about the abovementioned three questions. The written feedback was analyzed line by line by two authors (M.F.C. and M.L.L.) using an inductive approach of thematic analysis that relies on inductive reasoning with themes and subthemes emerging from students'

comments (Braun & Clarke, 2006). If there was any disagreement, a consultation with the senior author (C.C.Y.) was requested to reach an agreement.

RESULTS

Defining the baseline academic performance before Covid-19

The first semester of the 2019–2020 academic year was before the Covid-19 pandemic, so there was no difference in the teaching strategy or assessment process between the 2018–2019 academic year and the first semester of the 2019–2020 academic year. To evaluate the change in students' academic performance in learning anatomy between pre-Covid-19 and post-Covid-19, an appropriate baseline of student academic performance pre-Covid-19 needed to be defined. Therefore, students' examination scores on systematic anatomy and regional anatomy were compared between the two cohorts (Table 1). There was a significant difference between the lecture midterm and final examination scores of the first semester (86.49 ± 12.34 vs. 80.96 ± 12.62 ; $P < 0.001$; Cohen's $d = 0.44$) in the 2019–2020 cohort. In addition, there was a significant difference between the laboratory midterm and final examination scores of the first semester in the 2018–2019 cohort (84.56 ± 15.36 vs. 61.12 ± 19.71 ; $P < 0.001$; Cohen's $d = 1.33$) and the 2019–2020 cohort (89.89 ± 13.83 vs. 66.21 ± 20.65 ; $P < 0.001$; Cohen's $d = 1.35$). These results showed that the examination scores of systematic anatomy were significantly higher than those of regional anatomy within the same cohort, suggesting that the examination scores of systematic anatomy could not

be used as a baseline. Because the modified strategies of anatomy teaching began for regional anatomy in the second semester and the examination scores of systematic anatomy were different from those of regional anatomy, the final examination scores of the first semester may be appropriate as the baseline academic performance before Covid-19 to evaluate the difference in academic performance after Covid-19.

In addition, the examination scores of the 2019–2020 cohort, as shown in Table 1, were significantly higher than those of the 2018–2019 cohort in midterm lecture scores (86.49 ± 12.34 vs. 77.57 ± 15.75 ; $P < 0.001$; Cohen's $d = 0.63$), midterm laboratory scores (89.89 ± 13.83 vs. 84.56 ± 15.36 ; $P < 0.001$; Cohen's $d = 0.36$), final examination lecture scores (80.96 ± 12.62 vs. 77.89 ± 15.41 ; $p = 0.029$; Cohen's $d = 0.21$), and final examination laboratory scores (66.21 ± 20.65 vs. 61.12 ± 19.71 ; $P = 0.014$; Cohen's $d = 0.25$). These results showed that the academic performance of the 2019–2020 cohort was better than that of the 2018–2019 cohort, indicating that it would be inappropriate to directly compare the examination scores of these two cohorts to evaluate the influence of modified teaching strategies during the Covid-19 pandemic.

Change in examination scores of regional anatomy between the 2018–2019 and 2019–2020 cohorts

A straightforward method to evaluate the influence of modified teaching strategies during the Covid-19 pandemic was to compare the students' examination scores of the 2019–2020 cohort pre-Covid-19 with those post-Covid-19. Because the units covered in three regional anatomy examinations were different, the final

TABLE 1 Examination scores of the first semester between the 2018–2019 and the 2019–2020 cohorts before Covid-19

Cohort year/Type of examination/Student numbers (n)	Midterm examination Mean % (\pm SD)	Final examination Mean % (\pm SD)	Systematic anatomy versus regional anatomy	
			P-value	Cohen's <i>d</i>
Lecture score				
2018–2019 cohort (150)	77.57 (\pm 15.75)	77.89 (\pm 15.41)	0.859	0.02
2019–2020 cohort (156)	86.49 (\pm 12.34)	80.96 (\pm 12.62)	<0.001	0.44
Comparison of 2018–2019 versus 2019–2020 lecture scores				
P-value	<0.001	0.029		
Cohen's <i>d</i>	0.63	0.21		
Laboratory score				
2018–2019 cohort (150)	84.56 (\pm 15.36)	61.12 (\pm 19.71)	<0.001	1.33
2019–2020 cohort (156)	89.89 (\pm 13.83)	66.21 (\pm 20.65)	<0.001	1.35
Comparison of 2018–2019 versus 2019–2020 laboratory scores				
P-value	<0.001	0.014		
Cohen's <i>d</i>	0.36	0.25		

Note: P-value <0.05: Significant difference. Effect sizes: negligible (Cohen's $d < 0.2$); small ($0.2 \leq$ Cohen's $d < 0.5$); medium ($0.5 \leq$ Cohen's $d < 0.8$); large ($0.8 \leq$ Cohen's d).

examination scores of the first semester were compared with the midterm and final examination scores of the second semester separately in the 2018–2019 and 2019–2020 cohorts to understand whether different units covered in the examinations influenced the students' examination scores (Table 2). The midterm scores of the second semester were significantly higher than the final examination scores of the first semester for the lecture (92.12 ± 7.40 vs. 77.89 ± 15.41 ; $P < 0.001$; Cohen's $d = 1.18$) and laboratory examinations (75.76 ± 17.02 vs. 61.12 ± 19.71 ; $P < 0.001$; Cohen's $d = 0.79$) in the 2018–2019 cohort. A similar trend was observed in the 2019–2020 cohort in the lecture (91.59 ± 7.71 vs. 80.96 ± 12.62 ; $P < 0.001$; Cohen's $d = 1.02$) and laboratory examinations (69.50 ± 14.31 vs. 66.21 ± 20.65 ; $P = 0.03$; Cohen's $d = 0.18$). Furthermore, a similar trend was observed that the laboratory final examination scores for the second semester were significantly higher than those of the first semester in both the 2018–2019 cohort (66.05 ± 19.64 vs. 61.12 ± 19.71 ; $P = 0.03$; Cohen's $d = 0.25$) and the 2019–2020 cohort (70.61 ± 18.38 vs. 66.21 ± 20.65 ; $P = 0.04$; Cohen's $d = 0.22$). These data indicated that different anatomy units may influence the examination scores of medical students in both the anatomy lecture and laboratory examinations. Therefore, directly comparing the students' examination scores of the 2019–2020 cohort pre-Covid-19 with those post-Covid-19 would not be appropriate.

To avoid the influence of different units, the examination scores of the same units between the 2018–2019 and 2019–2020 cohorts were compared. Before Covid-19, the lecture final examination score of the first semester in the 2019–2020 cohort, as shown in Table 2, was higher than that of the 2018–2019 cohort (80.96 ± 12.62 vs. 77.89 ± 15.41 ; $P = 0.029$; Cohen's $d = 0.21$). A significant difference was also observed for the laboratory final examination scores of the first semester between the 2019–2020 and 2018–2019 cohorts (66.21 ± 20.65 vs. 61.12 ± 19.71 ; $P = 0.014$; Cohen's $d = 0.25$).

Furthermore, there was no difference in the lecture midterm scores between the cohorts (91.59 ± 7.71 vs. 92.12 ± 7.40 ; $P = 0.27$; Cohen's $d = 0.06$). In the laboratory midterm of the second semester, the trend was reversed. The laboratory score of the second semester in the 2019–2020 cohort was significantly lower than that in the 2018–2019 cohort (69.50 ± 14.31 vs. 75.76 ± 17.02 ; $P < 0.001$; Cohen's $d = 0.39$). In the final examination of the second semester, the lecture and laboratory scores of the 2019–2020 cohort were significantly higher than those of the 2018–2019 cohort (lecture: 82.21 ± 12.53 vs. 79.40 ± 11.17 ; $P = 0.02$; Cohen's $d = 0.23$; laboratory: 70.61 ± 18.38 vs. 66.05 ± 19.64 ; $P = 0.018$; Cohen's $d = 0.24$). These results showed that the performance trend of the midterm lecture and laboratory examinations of the second semester between the two cohorts was opposite to the other examinations. Since the midterm of the second semester in the 2019–2020 cohort happened during the time that modified teaching strategies during the Covid-19 pandemic started to be implemented, these results suggested that asynchronous online learning and smaller group dissections may influence student performance.

The influence of asynchronous online teaching on learning lecture courses of anatomy

Previous studies have documented the pros and cons of online assessments in medical education (Elsalem et al., 2021; Ikram & Rabbani, 2021; Meulmeester, et al., 2021; Sadeesh et al., 2021). Because face-to-face laboratory dissections and the procedure of laboratory assessments at the NTU after Covid-19 remained the same as those before Covid-19, laboratory performance could be used to evaluate the students' lecture performance to validate the results of the online lecture assessment. To evaluate the feasibility, Pearson correlation analysis between the lecture examination scores and laboratory examination scores in the 2018–2019 and 2019–2020 cohorts was conducted (Table 3). The results showed that the laboratory examination scores were significantly correlated with lecture examination scores, suggesting that laboratory examination scores may provide complementary information to understand the lecture academic performance of the students, and the laboratory final examination scores of the first semester could be a good subgroup index for investigating the effect of online lecture teaching after Covid-19.

A previous study adopted the difference in z-scores to quantify the change in students' academic performance due to different teaching strategies (Coelho, et al., 2019). In the current study, to evaluate the effect of modified teaching strategies after Covid-19, the difference in the lecture z-score, which represented the midterm and final examination z-scores in the second semester minus the final examination z-score in the first semester, was used. First, the laboratory final examination scores of the first semester were used to group the students into six subgroups as described above. Then, the difference in the lecture z-scores of individual students was shown to measure the change in lecture academic performance after the implementation of modified teaching strategies during the Covid-19 pandemic (Table 4). There was no significant difference between the difference in the z-score of the midterm and final examination (midterm: 0.25 ± 1.69 vs. 0.074 ± 1.19 ; $P = 0.35$; Cohen's $d = 0.12$; final examination: 0.55 ± 1.13 vs. 0.23 ± 0.69 ; $P = 0.16$; Cohen's $d = 0.33$) in the second semester between the 2018–2019 and 2019–2020 cohorts in the lowest group (laboratory score $< 12\%$). Similar trends were observed in the third quartile group ($25\% >$ laboratory score $\geq 12\%$), the upper median group ($75\% >$ laboratory score $\geq 50\%$), the upper first quartile group ($88\% >$ laboratory score $\geq 75\%$), and the highest group (laboratory score $\geq 88\%$) (Table 4). There was no significant difference in the difference of z-scores of the midterm and final examinations in the second semester between the 2018–2019 and 2019–2020 cohorts in the third quartile group (0.39 ± 0.81 vs. 0.04 ± 1.16 ; $P = 0.13$; Cohen's $d = 0.34$; 0.06 ± 0.79 vs. 0.05 ± 1.22 ; $P = 0.49$; Cohen's $d < 0.01$), the upper median group (-0.09 ± 0.50 vs. -0.16 ± 0.57 ; $P = 0.27$; Cohen's $d = 0.13$; -0.10 ± 0.76 vs. -0.11 ± 0.60 ; $P = 0.46$; Cohen's $d = 0.02$), the upper first quartile group (-0.21 ± 0.35 vs. -0.29 ± 0.49 ; $P = 0.28$; Cohen's $d = 0.18$; -0.09 ± 0.43 vs. -0.23 ± 0.68 ; $P = 0.21$; Cohen's $d = 0.25$), and the highest group (-0.35 ± 0.33 vs. -0.13 ± 0.52 ; $P = 0.07$; Cohen's

TABLE 2 Examination scores of regional anatomy in the 2018–2019 and 2019–2020 cohorts

Cohort year/Type of examination/ Student numbers (n)	First semester Final examination Mean % (\pm SD)	Second semester Midterm examination Mean % (\pm SD)	Second semester Final examination Mean % (\pm SD)	First semester final examination versus second semester midterm		First semester final examination versus second semester final examination	
				P-value	Cohen's <i>d</i>	P-value	Cohen's <i>d</i>
Lecture scores							
2018–2019 cohort (150)	77.89 (\pm 15.41)	92.12 (\pm 7.40)	79.40 (\pm 11.17)	<0.001	1.18	0.33	0.11
2019–2020 cohort (156)	80.96 (\pm 12.62)	91.59 (\pm 7.71)	82.21 (\pm 12.53)	<0.001	1.02	0.38	0.10
Comparison of 2018–2019 versus 2019–2020 lecture scores							
P-value	0.029	0.27	0.02				
Cohen's <i>d</i>	0.21	0.06	0.23				
Laboratory score							
2018–2019 cohort (150)	61.12 (\pm 19.71)	75.76 (\pm 17.02)	66.05 (\pm 19.64)	<0.001	0.79	0.03	0.25
2019–2020 cohort (156)	66.21 (\pm 20.65)	69.50 (\pm 14.31)	70.61 (\pm 18.38)	0.03	0.18	0.04	0.22
Comparison of 2018–2019 versus 2019–2020 laboratory scores							
P-value	0.014	<0.001	0.018				
Cohen's <i>d</i>	0.25	0.39	0.24				

Note: P-value <0.05: Significant difference. Effect sizes: negligible (Cohen's *d* < 0.2); small (0.2 \leq Cohen's *d* < 0.5); medium (0.5 \leq Cohen's *d* < 0.8); large (0.8 \leq Cohen's *d*).

TABLE 3 Correlation analysis between the regional anatomy lecture examination and regional anatomy laboratory examination in the 2018–2019 and 2019–2020 cohorts

Semester/Type of examination	Cohort year/Student numbers (n)	Lecture examination versus laboratory examination (Pearson r)	95% confidence interval	P-value
First semester Final examination	2018–2019 cohort (150)	0.7503	0.6707–0.8128	<0.0001
	2019–2020 cohort (156)	0.689	0.5964–0.7635	<0.0001
Second semester Midterm	2018–2019 cohort (150)	0.5465	0.4233–0.6499	<0.0001
	2019–2020 cohort (156)	0.5859	0.4722–0.6804	<0.0001
Second semester Final examination	2018–2019 cohort (150)	0.5906	0.4753–0.6859	<0.0001
	2019–2020 cohort (156)	0.6608	0.5620–0.7410	<0.0001

Note: Pearson r: Pearson's correlation; P-value <0.05: Significant correlation.

TABLE 4 Change in lecture academic performance between the 2018–2019 and the 2019–2020 cohorts post-Covid-19

Group	Type of examination in the second semester	Difference in lecture z-score Mean (\pm SD)		2018–2019 cohort versus 2019–2020 cohort	
		2018–2019 cohort Student numbers (n)	2019–2020 cohort	P-value	Cohen's d
Laboratory score <12%	Midterm	0.25 (\pm 1.69) (17)	0.07 (\pm 1.19) (18)	0.35	0.12
	Final examination	0.55 (\pm 1.13) (n = 17)	0.23 (\pm 0.69) (18)	0.16	0.33
12% \leq Laboratory score <25%	Midterm	0.39 (\pm 0.81) (21)	0.04 (\pm 1.16) (21)	0.13	0.34
	Final examination	0.06 (\pm 0.79) (21)	0.05 (\pm 1.22) (21)	0.49	0.01
25% \leq Laboratory score <50%	Midterm	0.04 (\pm 0.64) (37)	0.33 (\pm 0.66) (39)	0.03	0.44
	Final examination	-0.06 (\pm 0.67) (37)	0.16 (\pm 0.77) (39)	0.17	0.31
50% \leq Laboratory score <75%	Midterm	-0.09 (\pm 0.50) (n = 37)	-0.16 (\pm 0.57) (39)	0.27	0.13
	Final examination	-0.10 (\pm 0.76) (37)	-0.11 (\pm 0.60) (39)	0.46	0.02
75% \leq Laboratory score <88%	Midterm	-0.21 (\pm 0.35) (21)	-0.29 (\pm 0.49) (21)	0.28	0.18
	Final examination	-0.09 (\pm 0.43) (21)	-0.23 (\pm 0.68) (21)	0.21	0.25
88% \leq Laboratory score	Midterm	-0.35 (\pm 0.33) (17)	-0.13 (\pm 0.52) (18)	0.07	0.49
	Final examination	-0.15 (\pm 0.46) (17)	-0.13 (\pm 0.51) (18)	0.45	0.03

Note: P-value <0.05: Significant difference. Effect sizes: negligible (Cohen's $d < 0.2$); small ($0.2 \leq$ Cohen's $d < 0.5$); medium ($0.5 \leq$ Cohen's $d < 0.8$); large ($0.8 \leq$ Cohen's d).

$d = 0.49$; -0.15 ± 0.46 vs. -0.13 ± 0.51 ; $P = 0.45$; Cohen's $d = 0.03$). Nevertheless, in the lower median group (50% > laboratory score $\geq 25\%$), the difference in z-scores in the 2019–2020 cohort was significantly increased in the midterm scores of the second semester

(0.04 ± 0.64 vs. 0.33 ± 0.66 ; $P = 0.03$; Cohen's $d = 0.44$) but showed no difference in the final examination scores (-0.06 ± 0.67 vs. 0.16 ± 0.77 ; $P = 0.17$; Cohen's $d = 0.31$), (Table 4). These results suggested that asynchronous online learning may have a positive

influence on the lecture academic performance of the lower median group for learning anatomy after Covid-19 but may not have an effect on the lowest group, the third quartile group, the upper median group, the upper first quartile group, and the highest group. Furthermore, online anatomy lecture teaching was feasible and helpful for medical students in learning gross anatomy.

The influence of smaller group size for peer discussion in laboratory dissections

The lecture examination data were significantly correlated with the laboratory examination scores in the 2018–2019 and 2019–2020 cohorts (Table 3), suggesting that lower lecture examination scores could be a warning sign for anatomy teachers to identify the students who have a high risk of lower laboratory academic performance in learning anatomy dissections. Therefore, the lecture final examination score of the first semester could be a good subgrouping metric to understand the effect of smaller group size dissections on laboratory academic performance.

Before the onset of Covid-19, a larger group of 14–15 students, similar to TBL, were allocated a cadaver for laboratory dissections. A review consisting of peer discussions and interactions was conducted at the end of each anatomy unit. However, after Covid-19, the group size was limited to four students, and each smaller group had 2 hours for dissection in a rotation. To evaluate the effect of smaller group sizes, the lecture final examination scores of the first semester were used to group students into six subgroups. The difference in laboratory z-scores, which was based on the midterm and final examination z-scores in the second semester minus the final examination score in the first semester, was analyzed to measure the change in laboratory academic performance after the implementation of modified teaching strategies during the Covid-19 pandemic (Table S3).

In the lecture group with the lowest scores (lecture score <12%), the difference in the laboratory z-score in the second semester was not significantly different from that of the midterm between the two cohorts (0.46 ± 0.63 vs. 0.13 ± 0.97 ; $P = 0.12$; Cohen's $d = 0.12$), but it was significantly lower in the final examination scores (0.31 ± 0.74 vs. -0.28 ± 0.87 ; $P = 0.01$; Cohen's $d = 0.73$) in the 2019–2020 cohort (Table S3). In contrast, the difference in the laboratory z-scores of the lecture for the lower median group (50% > laboratory score $\geq 25\%$) in the final examination scores of the 2019–2020 cohort was significantly higher than that of 2018–2019 cohort (0.15 ± 0.60 vs. -0.17 ± 0.70 ; $P = 0.01$ Cohen's $d = 0.49$), while the difference in the laboratory z-score in the midterm showed no difference between the two cohorts (0.01 ± 0.87 vs. -0.19 ± 0.80 ; $P = 0.14$ Cohen's $d = 0.24$) (Table S3). No significant difference was found between the two cohorts for the other subgroups (Table S3). These results indicated that asynchronous online dissection guide teaching and a reduction in group size in laboratory anatomy provided positive benefits for the lower median group but had a negative influence on the lowest group in the 2019–2020 cohort in learning cadaver dissection.

Students' perception of modified teaching strategies during the Covid-19 pandemic

The quantitative responses to the ten-point Likert scale survey on the students' perceptions of teaching changes are shown in Figure 2. The survey were listed in Table S1. The response rate for the quantitative survey on the student's perceptions of teaching changes was 62.8% (98/156). The Cronbach's alpha of the Likert scale assay was 0.703 (0.609–0.768), which showed the acceptable reliability of this survey. Question 2—"Is teaching the anatomy dissection guide at the lecture hall helpful for learning anatomy?"—and question 3—"Is teaching the anatomy dissection guide via online video helpful for learning anatomy?"—were designed as a pair to compare traditional teaching with online teaching to understand which teaching strategy was helpful to medical students. The results showed significantly higher agreement with online teaching of dissection guide for learning anatomy (question 2 vs. question 3, 6.09 ± 2.66 vs. 8.13 ± 2.03 ; $P < 0.01$; Cohen's $d = 0.87$). Additionally, the results showed that most medical students agreed to use the online dissection-guide teaching video instead of traditional face-to-face teaching (8.09 ± 2.37). The analysis showed that most students agreed that they can benefit both from larger group size dissection and smaller group size dissection in learning anatomy (Question 5: 6.52 ± 2.47 ; Question 6: 6.51 ± 2.47 ; $P = 0.97$; Cohen's $d < 0.001$). The data from questions 7 and 8 indicated that students partially agreed that smaller laboratory groups may have insufficient learning time and peer discussion (question 7: 5.84 ± 2.98 ; question 8: 6.73 ± 2.76). The responses to questions 9 and 10 suggested that the students highly agreed that peer discussion is helpful for learning anatomy and preparing for examinations (question 9: 8.74 ± 1.84 ; question 10: 9.04 ± 1.52). In summary, these results suggested that students favored learning anatomy lectures and laboratory dissection guides through online videos. In addition, the highest agreement about the helpfulness of peer discussion in larger groups demonstrated that students appreciated the importance of peer learning in anatomy laboratory courses.

Different perceptions of peer discussion in larger group sizes in different grade subgroups

To further elucidate whether students with different academic performances have different perceptions regarding changes in teaching, the responses were analyzed according to grade groups: A⁺ ($n = 25$), A–A[–] ($n = 47$), B⁺–B[–] ($n = 18$), and C⁺–F ($n = 8$). As shown in Figure 3, the only significant difference between the grade groups was observed for question 9—"Peer discussion can provide benefits in learning anatomy" in which the A⁺ group gave higher credit to the importance of peer discussion than the other groups (A⁺ vs. A–A[–], 9.44 ± 0.96 vs. 8.51 ± 2.08 , $P = 0.019$, Cohen's $d = 0.71$; A⁺ vs. B⁺–B[–], 9.44 ± 0.96 vs. 8.50 ± 1.85 , $P = 0.018$, Cohen's $d = 0.67$; A⁺ vs. C⁺–F, 9.44 ± 0.96 vs. 8.50 ± 0.755 , $P = 0.044$, Cohen's $d = 0.52$). This result revealed that the importance of peer discussion was

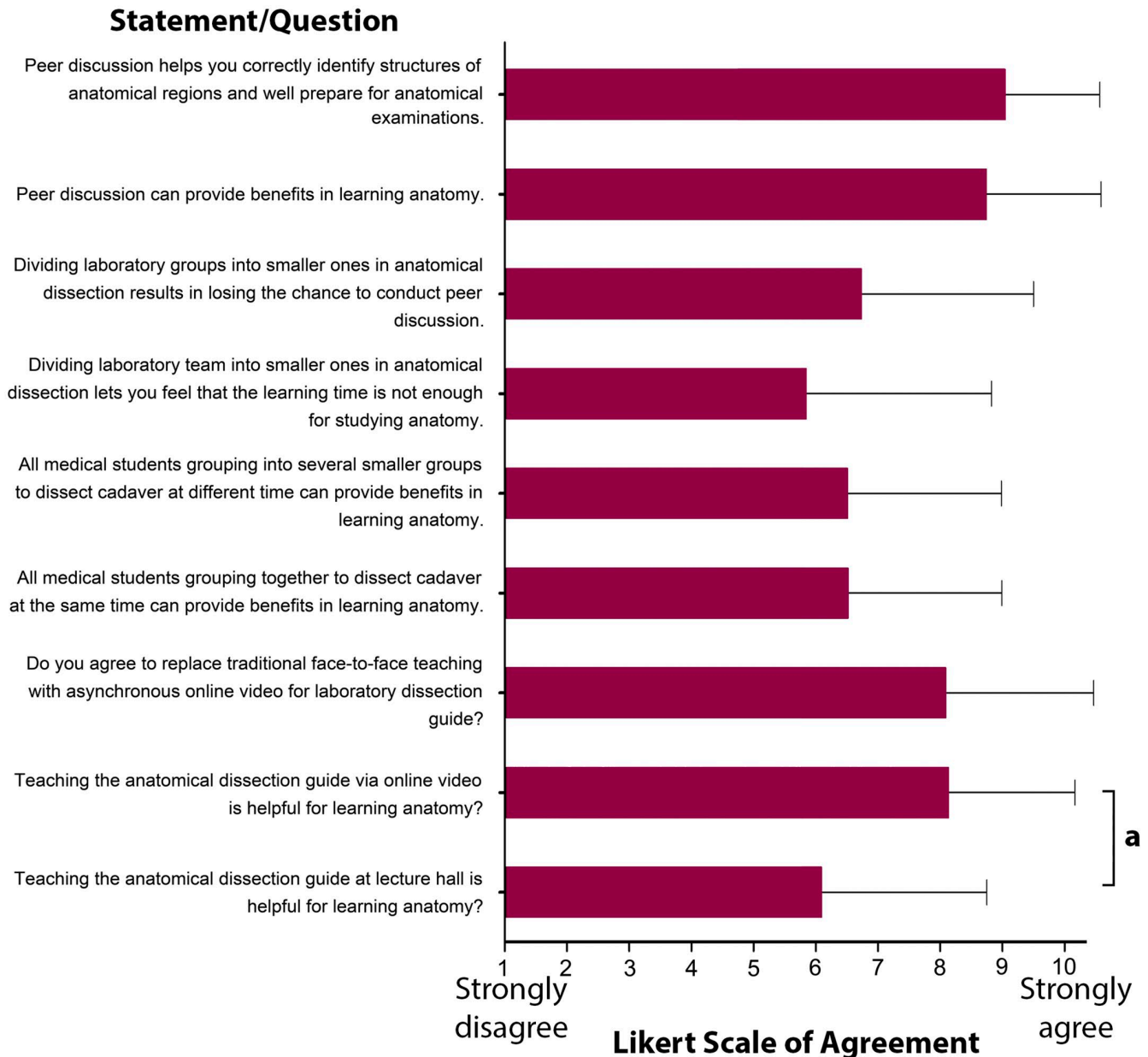


FIGURE 2 Analysis of students' perception of teaching changes. Students' responses toward teaching changes were analyzed with a ten-point Likert scale. A horizontal bar graph is shown as means \pm standard deviation (\pm SD) of agreement expressed on the Likert scale (1 = Strongly disagree, 10 = Strongly agree). ^a $P < 0.05$

significantly recognized by students with the highest academic performance (the A⁺ group) in comparison to the other groups.

Three major themes about modified teaching strategies during the Covid-19 pandemic and peer discussion in the qualitative analysis

The second part of the questionnaire was free-text responses to investigate the students' perceptions of modified teaching strategies and peer discussion in anatomy laboratory courses (Table S1). The data were analyzed by thematic analysis. Three major themes were explored, which included (1) the pros and cons of asynchronous

online learning of anatomy; (2) the influence of dividing laboratory groups into smaller ones on learning dissection; and (3) the importance of peer discussion for learning anatomy dissection. The results are summarized in Table S2.

In the current results, asynchronous online teaching videos were beneficial to most students because of the ability to play the videos repeatedly and learn at the students' own pace. "Being able to adjust video playing speed is helpful for personal learning and the learner can repeat the unclear parts of the video and search associated materials via the Internet at the same time" was a feedback from an A-grade student (Table S2). This could provide more help for students with weaker learning abilities to improve their anatomy academic performance in both theory and cadaver dissection. A B-grade

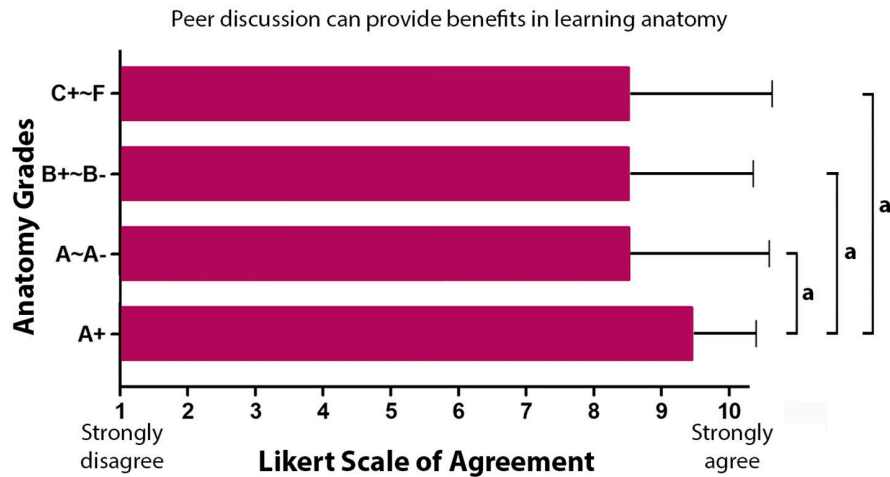


FIGURE 3 Analysis of benefits of peer discussion in four groups according to students' anatomy grades. The ten-point Likert scale responses to the question "Peer discussion can provide benefits in learning anatomy" were analyzed in four groups according to their anatomy grades: A⁺, A ~ A⁻, B⁺~B⁻ and C⁺~F. The agreement on this topic of the group with an A⁺ grade was significantly higher than that of other three groups. Likert scale points are: 1 = strongly disagree and 10 = strongly agree. Data are shown in means \pm standard deviation (\pm SD). ^a $P < 0.05$

student mentioned, "It is wonderful that I can play the dissection guide video again and again and can arrange the learning schedule by myself." Some disadvantages, such as missing the interaction between students and teachers, were also revealed—"I can't ask questions immediately while watching online videos." and "I preferred the interaction between teachers and students in the classroom."

Dividing laboratory groups into smaller ones provided fair practice opportunities and more time for dissection. Some mentioned that "The strategy that smaller groups conducted dissection at different times strictly according to the rotating roster was good to solve the problem of too many students dissecting at one time." and "Having more opportunities for dissecting cadavers made me learn anatomy more efficiently." The issue of depriving students from the right to practice was emphasized—"Some studious students would dissect cadavers in other's shift and deprive the right of other classmates' dissection."

Peer discussion provided huge learning benefits for medical students, such as promoting an understanding of the variation in different cadavers, reinforcing the impression of anatomy structures, avoiding misrecognition of anatomical structures, and helping organize fragmented knowledge of anatomy. Peer discussion during the review sessions played an important role for preparing students for the anatomy laboratory examination, especially for students with low academic performance. A C⁺ grade student in 2019–2020 mentioned that "Peer discussion is especially helpful for me to prepare for anatomy examinations."

According to the perception feedback results, asynchronous online videos could provide learning benefits for medical students in learning dissection guides. In addition, the results showed that some students may disrupt others' opportunities for laboratory dissection before Covid-19. In this study, the strategy of dividing the laboratory groups into smaller ones and setting a rotating roster provided an equal chance for each student to dissect. After modifying

the teaching strategy, lacking peer discussion in small groups may lead to a negative impact on the lowest grade group (score <12%) of medical students in the 2019–2020 cohort for learning dissection.

DISCUSSION

The Covid-19 pandemic has challenged anatomy teachers across the world to remotely teach and assess students in medical education. At NTU, asynchronous online videos were applied to continue teaching anatomy lectures and laboratory dissection. Additionally, dividing laboratory groups into smaller ones was conducted to help third-year medical students in the 2019–2020 cohort accomplish cadaver dissection at the end of the second semester. Hence, the experience and feedback of medical students in this group could provide information to explore the influence of asynchronous online teaching and smaller laboratory learning groups compared to traditional anatomy teaching. In this report, four important phenomena were documented, including: (1) the laboratory academic performance of medical students experiencing the modified teaching strategies of asynchronous online teaching and rotating smaller group sizes in practical dissections decreased at the beginning of Covid-19; (2) the laboratory assessment strategy at NTU could provide accessory methods to evaluate the academic performance of online lecture assessments; (3) using the lecture examination scores to predict laboratory academic performance could be feasible; and (4) the change from larger to smaller group sizes in practical dissection influenced medical students on learning cadaver dissections. These results could help anatomy teachers understand the influence of teaching strategies and the perceptions of medical students on learning anatomy under limited crowd-gathering rules. In addition, this study provided valuable information, which could improve online anatomy lectures and laboratory cadaver dissections for anatomy teachers in the future.

Temporary influence of medical students from implementing modified teaching strategies during the Covid-19 pandemic in learning gross anatomy

In this report, the lecture and laboratory examination scores of systematic anatomy and regional anatomy in the 2019–2020 cohort were significantly higher than those in the 2018–2019 cohort before Covid-19 (Tables 1 and 2), suggesting that the academic performance of the 2019–2020 cohort was better than that of the 2018–2019 cohort. However, at the beginning of Covid-19, implementing modified teaching strategies resulted in the disappearance of this trend, although it returned at the end of the second semester. These results suggested that implementing modified teaching strategies had a temporary negative impact on medical students in learning gross anatomy. Since the onset of the Covid-19 pandemic, changes in teaching strategies might happen in teaching gross anatomy (Pather, et al., 2020; Harmon et al., 2021; Tucker & Anderson, 2021). Previous reports showed that online learning provided benefits for students in terms of their grades and feedbacks (Barbagallo et al., 2020; Yoo et al., 2021; Al-Neklawy & Ismail, 2022), but there may be a temporary negative influence on medical students in learning anatomy according to the findings of this study. Therefore, these results suggested that anatomy teachers should consider that students may spend time becoming proficient in modified teaching strategies, although digital teaching was ultimately beneficial for students. Hence, anatomy teachers need to arrange the schedule keeping this in mind when implementing modified teaching strategies. For example, arranging extra time to respond students' questions via online blackboards or forums could be a useful strategy to help students get used to modified teaching strategies (Green, et al., 2018; Al-Neklawy & Ismail, 2022).

The feasibility of accessory strategies for evaluating the academic performance of online lecture assessments

Many universities adopted online assessments to evaluate medical students' academic performance in gross anatomy after the outbreak of Covid-19 (Elzainy, et al., 2020; Sadeesh, et al., 2021). Many universities proctored students' behavior online during examinations through webcams or other assessment tools (Alessio, 2017; Sindiani et al., 2020; Elsalem, et al., 2021). However, medical students worried about unjustified invalidation of their examinations due to unstable Internet connections, background noise, webcam issues, and privacy issues (Meulmeester, et al., 2021). In the present study, the high correlation between laboratory and lecture examination scores before and after Covid-19 onset (Table 3) could provide a complementary way to evaluate students' online lecture performance through laboratory examination scores. In addition, the differences in lecture z-scores assessed via subgrouping laboratory examination scores showed that there were few changes in the lecture examinations of the second semester in the 2018–2019 and 2019–2020 cohorts before and after Covid-19 onset, suggesting that using laboratory examination scores

to subgroup lecture examination scores was reasonable. Therefore, this method provided another possibility to evaluate students' online lecture academic performance and mitigated some of the disadvantages of online lecture assessments.

Although the 2019–2020 cohort experienced asynchronous online lecture courses, the students still took conventional lecture examinations. Therefore, this provided a good opportunity to compare the change in lecture academic performance with the 2018–2019 cohort. In the present study, the difference in lecture z-scores in the lower median group (50% > laboratory score \geq 25%) in the 2019–2020 cohort increased in the midterm scores of the second semester (Table 4), suggesting that online learning provided benefits for some medical students from pre-Covid-19 to post-Covid-19. This result was similar to several recent studies that documented the advantages of remote learning since the onset of the Covid-19 pandemic (Pyatt & Sims, 2012; Barash, et al., 2021; Cheng, et al., 2021; Harrell, et al., 2021; Zarcone & Saverino, 2022). According to these results, teachers could suggest that students with lower median academic performance preferentially adopt online lecture courses to meet the restriction rules in the classroom during the Covid-19 pandemic.

The feasibility of predicting laboratory academic performance through the performance of lecture examinations

Practical dissection is important for medical students to form professional identities and gain confidence, strength, and practical skills (Parker & Randall, 2020). Therefore, it is important for anatomy teachers to determine which students with low academic performance in practical dissection would benefit from extra help. In this study, the high correlation between the lecture and laboratory examination scores before and after the onset of Covid-19 (Table 3) indicated the possibility of predicting laboratory performance via evaluating students' lecture performance. In addition, the differences in laboratory z-scores by subgrouping students by their lecture examination scores showed that there were few changes in the laboratory examinations of the second semester in the 2018–2019 and 2019–2020 cohorts before and after Covid-19 onset, suggesting that using lecture examination scores to subgroup laboratory examination scores was reasonable. Therefore, predicting students' laboratory academic performance through lecture examination scores is a feasible strategy for medical schools at which the lecture courses and cadaver dissections are delivered in different semesters. With information on lecture examination scores, anatomy teachers could give students with low lecture performance extra help while supervising practical dissections, and the efficiency of face-to-face dissection teaching could be improved.

In addition, the difference in laboratory z-scores could demonstrate a change in academic performance due to different laboratory learning strategies. In the present study, the difference in laboratory z-scores in the lower median group (50% > lecture score \geq 25%) in the 2019–2020 cohort was increased in the final examination scores of the second semester (Table S3). Furthermore, the ten-point Likert scale

survey in this report showed that most students preferred asynchronous online teaching dissection videos for learning practical dissection (Figure 2). In addition, the free-text feedback from a B-grade student mentioned that watching the dissection guide videos repeatedly was beneficial for learning practical dissection (Table S2). Moreover, several previous reports documented the benefits of online learning (Green, et al., 2018; Barash, et al., 2021; Cheng, et al., 2021; Eansor et al., 2022; Mahdy & Sayed, 2022; Zarcone & Saverino, 2022). Taken together, asynchronous online dissection videos could provide more help for students with weaker learning abilities to improve their academic performance in cadaver dissection. According to these results, anatomy teachers may suggest that students, especially those with lower median academic performance, watch dissection videos to preview and review the material to improve their learning of dissection.

The influence of reducing group size and peer discussion on learning practical dissection

Many medical colleges have adopted TBL for teaching cadaver dissection (Inuwa, 2012; Isbell et al., 2016; Chang, et al., 2019). The size of dissection groups is dependent on many factors, such as student number and cadaver availability. In previous studies, the group sizes were mostly 6–8 students per group (Bentley & Hill, 2009; Evans & Cuffe, 2009; Han, et al., 2015; Nwachukwu, et al., 2015; Rowland & Joy, 2015; Burgess et al., 2018). In the present study, the group size of the 2019–2020 cohort was reduced from 14–15 to 4 students after the onset of Covid-19. According to feedback from the 2019–2020 cohort, large group size with peer discussion could help students avoid misrecognizing anatomical structures, help them organize fragmented anatomical knowledge, and promote understanding of the variation between different cadavers (Table S2), suggesting that large group size provided the benefit of collective intelligence from different students to solve complex classroom problems. This advantage of large groups was also mentioned in other TBL studies (Thompson, et al., 2015). Therefore, learning practical dissections with large group sizes (14–15 per group) could provide medical students with benefits from collective intelligence.

Peer discussion is important for medical students in TBL learning and is a core element of TBL (Inuwa, 2012; Parmelee et al., 2012; Han, et al., 2015; Preece, 2015; Nishigawa et al., 2017; Yoon et al., 2018; Singh et al., 2019). In the 2019–2020 cohort, reducing group size in dissections was accompanied with reduced peer discussion. The lowest grade group (score <12%) of medical students in the 2019–2020 cohort showed significantly decreased laboratory academic performance in the final examination than that in the 2018–2019 cohort. Furthermore, the ten-point Likert scale survey in this report had the highest agreement (9.04/10 points) for the question that peer discussion helped students prepare better for examinations and laboratory dissections. Additionally, a qualitative description from a C⁺ grade student mentioned that peer discussion was helpful in preparing for examinations. Although the possibility of dislike of low performing students for the change in laboratory design

during such a volatile could not be excluded, the above results indicated that lacking peer discussion may be a factor related to the negative impact on students with a low academic performance, and peer discussion could provide learning benefits for medical students in TBL-like practical dissection groups. Therefore, learning cadaver dissection accompanied with peer discussion should be emphasized when the teachers redesign anatomy courses in the future, especially during situations like the Covid-19 pandemic.

Despite the advantages of large group size, previous studies have shown some disadvantages of TBL, including a few students doing all the work in the team, the team ignoring the opinion of some students, and high-functioning individuals jostling for the “alpha rank” within a team, which diminished team cohesion (Swaab, et al., 2014; Thompson, et al., 2015; Khansari & Coyne, 2018). Similar disadvantages were also proposed by students of the 2019–2020 cohort that some students disrupted others’ dissecting opportunities before Covid-19. This disadvantage may explain why the A-to-F grade groups did not favor peer discussion as much as the A⁺-grade group (Figure 3). In this study, the strategy of dividing laboratory groups into smaller ones and setting a rotating roster provided an equal chance for each student to dissect, although anatomy teachers at NTU had previously asked medical students to set a rotating roster to ensure that every student had the same opportunity to do hands-on dissection before the Covid-19 pandemic. Based on the current results, anatomy teachers must be aware of the balance of learning opportunities provided to each student and should pay more attention to asking disruptive students not to interrupt others’ dissections. These notable findings could provide important information for improving dissection teaching.

Limitations of this study

There are some limitations in this study. First, the response rate of the questionnaire was 62.8% ($n = 98$). More than half of questionnaire responses were contributed by students with an A⁺ or above; this disproportion in responses from the best-performing subgroups may mean that the results do not completely represent the opinions of all medical students. Second, the sample size of each subgroup between the two cohorts was too small to pass Bonferroni’s multiple comparison test P -value, suggesting that there may be low statistical power. However, a previous study documented that the type II error rate was increased after Bonferroni correction (Perneger, 1998). To avoid the risk of type I and type II errors, the Cohen’s d value was presented accompanied with the P -value in the current study (Kim et al., 2021b). Third, the questionnaire was designed without balancing positive and negative indicators, which may create a bias for its interpretation. Fourth, asynchronous online teaching dissection guides and reduced group sizes were announced at the same time after the onset of Covid-19, so it was difficult to determine which modification had a stronger impact on student performance. Finally, this study is hard to replicate because the level of interruption in anatomy courses during the Covid-19 pandemic is different around the world. In Taiwan, only the third-year medical students in the 2019–2020 cohort experienced

traditional teaching, asynchronous online teaching, and the division of laboratory groups into smaller ones for learning gross anatomy within a single academic year. In the future, the authors could try to eliminate the limitations of this study to evaluate the influence of changing teaching methods from traditional teaching to online teaching.

Future work

Several studies have shown that online forums or blackboards could benefit students in learning anatomy (Green, et al., 2018; Al-Neklawy & Ismail, 2022), so multimedia platforms may provide solutions for lacking peer discussion in dissection in smaller groups through Google Classroom, Google Meet, or other multimedia platforms. Furthermore, anatomy teachers could combine traditional face-to-face teaching and online learning tools, such as a blended learning system for teaching gross anatomy in the future. In addition, applying online interviews to evaluate students' academic performance through online communication platforms could be another accessory evaluation strategy to mitigate the disadvantages of online lectures or laboratory assessments.

CONCLUSIONS

There are five important conclusions of this study. First, online learning of anatomy lectures and dissection guides had beneficial effects on learning in anatomy courses. Second, a change in teaching strategies may temporarily negatively influence the ability of medical students to learn anatomy, so anatomy teachers should give students some time to adapt to these changes. Third, analyzing the performance of laboratory assessments could be a complementary strategy to evaluate online assessments. Fourth, applying lecture examination scores to predict laboratory performance was feasible, which could provide a warning sign to teachers about which students may have difficulty in learning during the practical dissection units. Finally, reducing group size together with reduced peer discussion may have a negative effect on learning cadaver dissection for students with low academic performance, and the collective intelligence within large group sizes may be an important factor for medical students in learning practical dissection. In summary, these findings provide useful information for anatomists to develop new teaching strategies for gross anatomy courses in the future.

ACKNOWLEDGMENTS

This work was supported by grants to Ming-Fong Chang from the Ministry of Science and Technology (MOST 109-2511-H-002-020) and the Ministry of Education (PMN1100547); grants to Meng-Lin Liao from the Ministry of Science and Technology (MOST 110-2511-H-002-020-MY3). We would like to thank our students for agreeing to participate in this study. We also appreciate the assistance from Yu-Chin Chen, Yu-Jen Ko, Pei-Jung Cheng, Yaw-Hua Yang, and Yu-Yen Hsiao in the Department of Anatomy and Cell Biology, College of Medicine, National Taiwan University, Taipei, Taiwan.

CONFLICT OF INTEREST

The authors declare no competing financial interests.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Informed consent for data collection was obtained from all participants. Ethical approval (202011HS019 and 201905HS165) was obtained from the Research Ethics Committee of the National Taiwan University.

ORCID

Ming-Fong Chang  <https://orcid.org/0000-0002-4522-7669>

Meng-Lin Liao  <https://orcid.org/0000-0002-2293-319X>

Chi-Chuan Yeh  <https://orcid.org/0000-0003-4455-8981>

REFERENCES

- Akinola OB. 2011. Formal body bequest program in Nigerian medical schools: When do we start? *Anat Sci Educ* 4:239–242.
- Al-Neklawy AF, Ismail AS. 2022. Online anatomy team-based learning using blackboard collaborate platform during COVID-19 pandemic. *Clin Anat* 35:87–93.
- Alessio H, Malay N, Maurer K, Bailer AJ, Rubin B. 2017. Examining the effect of proctoring on online test scores. *Online Learn* 21:146–161.
- Barash A, Dickman N, Karasik D. 2021. Educating future doctors in Covid-19 times: Anatomists lead the way! *Anat Sci Educ* 14:426–427.
- Barbagallo MS, Porter JE, Lamunu M. 2020. Evaluation of a blended online and digital learning mode of anatomy and physiology for undergraduate nursing students. *Comput Inform Nurs* 38:633–637.
- Bentley BS, Hill RV. 2009. Objective and subjective assessment of reciprocal peer teaching in medical gross anatomy laboratory. *Anat Sci Educ* 2:143–149.
- Braun V, Clarke V. 2006. Using thematic analysis in psychology. *Qual Res Psychol* 3:77–101.
- Burgess A, Ramsey-Stewart G, Mellis C. 2016. Anatomy by whole body dissection: A new Masters of Surgery course. *ANZ J Surg* 86:665–669.
- Burgess A, Roberts C, Ayton T, Mellis C. 2018. Implementation of modified team-based learning within a problem based learning medical curriculum: A focus group study. *BMC Med Educ* 18:74.
- Chang MF, Liao ML, Hsieh ST, Wang SH, Lee LJ, Kung HN, Lu KS, Chen YL, Lue JH. 2019. Benefit of writing laboratory previews for anatomy learning in medical student. *J Med Educ* 23:185–196.
- Cheng HY, Huang AS. 2021. Proactive and blended approach for COVID-19 control in Taiwan. *Biochem Biophys Res Commun* 538:238–243.
- Cheng X, Chan LK, Pan SQ, Cai H, Li YQ, Yang X. 2021. Gross anatomy education in China during the Covid-19 pandemic: A national survey. *Anat Sci Educ* 14:8–18.
- Cheng X, Ka Ho Lee K, Chang EY, Yang X. 2017. The “flipped classroom” approach: Stimulating positive learning attitudes and improving mastery of histology among medical students. *Anat Sci Educ* 10:317–327.
- Coelho C, Zahra D, Ali K, Tredwin C. 2019. To accept or decline academic remediation: What difference does it make? *Med Teach* 41:824–829.
- Detton AJ. 2016. *Grant's Dissector Videos for Grant's Dissector*. 16th Ed. Philadelphia, PA: Wolters Kluwer, Lippincott, Williams & Wilkins. 323 p.
- Detton AJ. 2020. *Grant's Dissector Videos for Grant's Dissector*. 17th Ed. Philadelphia, PA: Wolters Kluwer, Lippincott, Williams & Wilkins. 326 p.
- Eansor P, Norris ME, D'Souza LA, Bauman GS, Kassam Z, Leung E, Nichols AC, Sharma M, Tay KY, Velker V, Warner A, Willmore KE, Campbell N, Palma DA. 2022. Is remote learning as effective as in-person learning for contouring education? A prospective comparison of

- face-to-face versus online delivery of the anatomy and radiology contouring bootcamp. *Int J Radiat Oncol Biol Phys* 112:590–599.
- Elsalem L, Al-Azzam N, Jum'ah AA, Obeidat N. 2021. Remote E-exams during Covid-19 pandemic: A cross-sectional study of students' preferences and academic dishonesty in faculties of medical sciences. *Ann Med Surg (Lond)* 62:326–333.
- Elzainy A, El Sadik A, Al Abdulmonem W. 2020. Experience of e-learning and online assessment during the COVID-19 pandemic at the College of Medicine, Qassim University. *J Taibah Univ Med Sci* 15:456–462.
- Evans DJ, Cuffe T. 2009. Near-peer teaching in anatomy: An approach for deeper learning. *Anat Sci Educ* 2:227–233.
- Evans DJ, Bay BH, Wilson TD, Smith CF, Lachman N, Pawlina W. 2020. Going virtual to support anatomy education: A STOPGAP in the midst of the Covid-19 pandemic. *Anat Sci Educ* 13:279–283.
- Franchi T. 2020. The impact of the Covid-19 pandemic on current anatomy education and future careers: A student's perspective. *Anat Sci Educ* 13:312–315.
- Gangata H, Ntaba P, Akol P, Louw G. 2010. The reliance on unclaimed cadavers for anatomical teaching by medical schools in Africa. *Anat Sci Educ* 3:174–183.
- Gillett-Swan J. 2017. The challenges of online learning supporting and engaging the isolated learner. *J Learn Des* 10:20–30.
- Green RA, Whitburn LY, Zacharias A, Byrne G, Hughes DL. 2018. The relationship between student engagement with online content and achievement in a blended learning anatomy course. *Anat Sci Educ* 11:471–477.
- Han ER, Chung EK, Nam KI. 2015. Peer-assisted learning in a gross anatomy dissection course. *PLoS One* 10:e0142988.
- Harmon DJ, Attardi SM, Barremkala M, Bentley DC, Brown KM, Dennis JF, Goldman HM, Harrell KM, Klein BA, Ramnanan CJ, Richtsmeier JT, Farkas GJ. 2021. An analysis of anatomy education before and during Covid-19: May–August 2020. *Anat Sci Educ* 14:132–147.
- Harrell KM, McGinn MJ, Edwards CD, Warren Foster K, Meredith MA. 2021. Crashing from cadaver to computer: Covid-driven crisis-mode pedagogy spawns active online substitute for teaching gross anatomy. *Anat Sci Educ* 14:536–551.
- Holland JC, Ni Dhonaill R, Clarke M, Joyce P. 2021. Physician associate students' experience of anatomy dissection. *Anat Sci Educ* 14:52–61.
- Huynh N, Burgess A, Wing L, Mellis C. 2021. Anatomy by whole body dissection as an elective: Student outcomes. *J Surg Educ* 78:492–501.
- Ikram F, Rabbani MA. 2021. Academic integrity in traditional vs online undergraduate medical education amidst COVID-19 pandemic. *Cureus* 13:e13911.
- Inuwa IM. 2012. Perceptions and attitudes of first-year medical students on a modified team-based learning (TBL) strategy in anatomy. *Sultan Qaboos Univ Med J* 12:336–343.
- Isbell JA, Makeeva V, Caruthers K, Brooks WS. 2016. The impact of team-based learning (TBL) on physician assistant students' academic performance in gross anatomy. *J Physician Assist Educ* 27:126–130.
- Khansari PS, Coyne L. 2018. An innovative addition to team-based-learning pedagogy to enhance teaching and learning: Students' perceptions of team exams. *Curr Pharm Teach Learn* 10:90–95.
- Kim D, Yoo H, Lee YM, Rhyu IJ. 2021a. Lessons from cadaver dissection during the COVID-19 pandemic. *J Korean Med Sci* 36:e188.
- Kim DH, Lee HJ, Lin Y, Kang YJ. 2021b. Changes in academic performance in the online, integrated system-based curriculum implemented due to the COVID-19 pandemic in a medical school in Korea. *J Educ Eval Health Prof* 18:24.
- Koop CF, Marscholke M, Schmiedl A, Proskynitopoulos PJ, Behrends M. 2021. Does an audiovisual dissection manual improve medical students' learning in the gross anatomy dissection course? *Anat Sci Educ* 14:615–628.
- Li L, Li L, Zuo Y. 2020. A hands-on organ-slicing activity to teach the cross-sectional anatomy. *Anat Sci Educ* 13:732–742.
- Liu YC, Kuo RL, Shih SR. 2020. COVID-19: The first documented coronavirus pandemic in history. *Biomed J* 43:328–333.
- Longhurst GJ, Stone DM, Duloherly K, Scully D, Campbell T, Smith CF. 2020. Strength, weakness, opportunity, threat (SWOT) analysis of the adaptations to anatomical education in the United Kingdom and Republic of Ireland in response to the Covid-19 pandemic. *Anat Sci Educ* 13:301–311.
- Mahdy MA, Sayed RK. 2022. Evaluation of the online learning of veterinary anatomy education during the Covid-19 pandemic lockdown in Egypt: Students' perceptions. *Anat Sci Educ* 15:67–82.
- Meulmeester FL, Dubois EA, Krommenhoek-van Es CT, de Jong PG, Langers AM. 2021. Medical Students' Perspectives on Online Proctoring During Remote Digital Progress Test. *Med Sci Educ* 31:1–5.
- Nishigawa K, Hayama R, Omoto K, Okura K, Tajima T, Suzuki Y, Hosoki M, Ueda M, Inoue M, Rodis OM, Matsuka Y. 2017. Validity of peer evaluation for team-based learning in a dental school in Japan. *J Dent Educ* 81:1451–1456.
- Nwachukwu C, Lachman N, Pawlina W. 2015. Evaluating dissection in the gross anatomy course: Correlation between quality of laboratory dissection and students outcomes. *Anat Sci Educ* 8:45–52.
- O'Leary JM, McNeely DE, Damp JA, Wells QS, Nanney L, Mendes L. 2019. Hands-on gross anatomy instruction improves clinical imaging skills among cardiovascular fellows. *J Med Educ Curric Dev* 6:2382120519842542.
- Parker E, Randall V. 2020. Learning beyond the basics of cadaveric dissection: A qualitative analysis of non-academic learning in anatomy education. *Med Sci Educ* 31:147–153.
- Parmelee D, Michaelsen LK, Cook S, Hudes PD. 2012. Team-based learning: A practical guide: AMEE guide no. 65. *Med Teach* 34:e275–e287.
- Pathner N, Blyth P, Chapman JA, Dayal MR, Flack NA, Fogg QA, Green RA, Hulme AK, Johnson IP, Meyer AJ, Morley JW, Shortland PJ, Štrkalj G, Štrkalj M, Valter K, Webb AL, Woodley SJ, Lazarus MD. 2020. Forced disruption of anatomy education in Australia and New Zealand: An acute response to the Covid-19 pandemic. *Anat Sci Educ* 13:284–300.
- Perneger TV. 1998. What's wrong with Bonferroni adjustments. *BMJ* 316:1236–1238.
- Preece R. 2015. Peer-assisted learning for clinical anatomy. *Med Teach* 37:300–301.
- Pyatt K, Sims R. 2012. Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access. *J Sci Educ Technol* 21:133–147.
- Rowland KC, Joy A. 2015. The gross anatomy laboratory: A novel venue for critical thinking and interdisciplinary teaching in dental education. *J Dent Educ* 79:295–300.
- Ruijsbroek A, Wijga AH, Gehring U, Kerkhof M, Droomers M. 2015. School performance: A matter of health or socio-economic background? Findings from the PIAMA birth cohort study. *PLoS One* 10:e0134780.
- Sadeesh T, Prabavathy G, Ganapathy A. 2021. Evaluation of undergraduate medical students' preference to human anatomy practical assessment methodology: A comparison between online and traditional methods. *Surg Radiol Anat* 43:531–535.
- Simmerman E, Simmerman A, Lassiter R, King R, Ham B, Adam BL, Ferdinand C, Holsten S. 2018. Feasibility and benefit of incorporating a multimedia cadaver laboratory training program into a didactics curriculum for junior and senior surgical residents. *J Surg Educ* 75:1188–1194.
- Sindiani AM, Obeidat N, Alshdaifat E, Elsalem L, Alwani MM, Rawashdeh H, Fares AS, Alalawne T, Tawalbeh LI. 2020. Distance education during the COVID-19 outbreak: A cross-sectional study among medical students in North of Jordan. *Ann Med Surg (Lond)* 59:186–194.
- Singh K, Bharatha A, Sa B, Adams OP, Majumder MAA. 2019. Teaching anatomy using an active and engaging learning strategy. *BMC Med Educ* 19:149.

- Srinivasan DK. 2020. Medical students' perceptions and an anatomy teacher's personal experience using an e-learning platform for tutorials during the Covid-19 crisis. *Anat Sci Educ* 13:318–319.
- Sultan AS. 2018. The flipped classroom: An active teaching and learning strategy for making the sessions more interactive and challenging. *J Pak Med Assoc* 68:630–632.
- Swaab RI, Schaerer M, Anicich EM, Ronay R, Galinsky AD. 2014. The too-much-talent effect: Team interdependence determines when more talent is too much or not enough. *Psychol Sci* 25:1581–1591.
- Thompson BM, Haidet P, Borges NJ, Carchedi LR, Roman BJ, Townsend MH, Butler AP, Swanson DB, Anderson MP, Levine RE. 2015. Team cohesiveness, team size and team performance in team-based learning teams. *Med Educ* 49:379–385.
- Tucker RP, Anderson H. 2021. Dissection experience and performance on a human gross anatomy written examination: Lessons learned during the Covid-19 pandemic. *Anat Sci Educ* 14:169–170.
- Vasan NS, DeFouw DO, Compton S. 2011. Team-based learning in anatomy: An efficient, effective, and economical strategy. *Anat Sci Educ* 4:333–339.
- Yoo H, Kim D, Lee YM, Rhyu IJ. 2021. Adaptations in anatomy education during COVID-19. *J Korean Med Sci* 36:e13.
- Yoon HB, Park WB, Myung SJ, Moon SH, Park JB. 2018. Validity and reliability assessment of a peer evaluation method in team-based learning classes. *Korean J Med Educ* 30:23–29.
- Zarcone D, Saverino D. 2022. Online lessons of human anatomy: Experiences during the COVID-19 pandemic. *Clin Anat* 35:121–128.

AUTHOR BIOGRAPHIES

Ming-Fong Chang, Ph.D., is an assistant professor in the Department of Anatomy and Cell Biology, College of Medicine at the National Taiwan University, Taipei, Taiwan. He teaches gross anatomy, histology, and neuroanatomy to medical students and has a strong interest in information technology-enhanced learning and how it can be used to support students' learning for improving medical education.

Meng-Lin Liao, Ph.D., is an assistant professor in the Department of Anatomy and Cell Biology, College of Medicine at the National Taiwan University, Taipei, Taiwan. She teaches gross anatomy, histology, and neuroanatomy to medical students, and her research interest is in developmental biology and medical education.

June-Horng Lue, Ph.D., is a professor in the Department of Anatomy and Cell Biology, College of Medicine at the National Taiwan University, Taipei, Taiwan. He teaches gross anatomy, histology, embryology, and neuroanatomy to medical students.

Chi-Chuan Yeh, M.D., M.Ed., Ph.D., is a surgeon in the Department of Surgery at the National Taiwan University Hospital, College of Medicine, National Taiwan University, Taipei, Taiwan. Her clinical works focus on hernia surgery and minimally invasive surgery. Her research interests are in the development of models for training minimally invasive surgery and open surgery as well as surgical and medical education.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Chang M-F, Liao M-L, Lue J-H, Yeh C-C. 2022. The impact of asynchronous online anatomy teaching and smaller learning groups in the anatomy laboratory on medical students' performance during the Covid-19 pandemic. *Anat Sci Educ* 00:1–17. <https://doi.org/10.1002/ase.2179>