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Review Article

Comparison of conventional- versus technology-aided histology teaching for medical students – A meta-analysis

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ABSTRACT

Reduction in histology teaching hours, limited attention span of students, provoked medical educator to adopt to tools where teaching and learning outcome is effective. Availability of such research work kindled the authors to compare the effectiveness of learning outcome of technology aided microanatomy (TAM) teaching with conventional teaching (CT). The objective was to compare the learning outcome of TAM with CT amongst medical students. Data sources: PubMed, MEDLINE, ScienceDirect, SCOPUS, Cochrane, Web of knowledge, and Google Scholar. Study selection: The meta-analysis included all published studies indulged in trailing various methods of histology teaching and focussed on assessing its learning outcome. The learning outcome was assessed by the learner's score. Data extraction was guided by a predetermined checklist. Analytical approach: Using RevMan 5 software, the mean difference of learning outcome among medical students with TAM and CT of histology were compared. Main outcomes and measures: The learning outcome of CT group was significantly high on comparing with the TAM learning group. Meta-analysis involved 837 subjects who had TAM methods and 1047 subjects who received CT method (Control group) showed an overall significant effect in favor of control group (MD = 0.08, 95% CI 0.05–0.12, $P < 0.001$). A significant Q statistic ($P < 0.001$) indicated the presence of considerable heterogeneity ($I^2 = 100\%$) which could be due to varied demography and more recent studies. This systematic review and meta-analysis demonstrated no positive effect in the enhancement of learning outcome of medical students with TAM teaching and the conventional teaching still upholds its esteem.

Keywords: Conventional histology teaching, Virtual microscopy, Flipped histology classroom, Histology atlas, Self-directed histology learning

INTRODUCTION

Teaching anatomy disciplines especially histology is challenging and needs more interest and time for teaching and learning. Understanding the cellular architect is mandatory to master histopathology.[1] Conventional learning encompasses routine didactic lectures followed by facilitator-assisted learning of histological images using an optical microscope in the laboratory. Conventional learning at the laboratory requires active involvement and interaction among students. Increasing students entry, disproportioned teacher-student ratio, and limited financing for infrastructure paved the upbringing of technology adopted of microanatomy lectures.[2]

Self-evaluation of learned images before assessment which was strenuous with conventional histology learning can be addressed by adopting computer-assisted teaching, as the millennials are also tech-savvy. The asynchronous technology assisted tools comfort learners to learn at their own pace.[3] Digitalization of learning resources makes the student a better life long learner. Reduction in histology teaching hours, limited attention span of students provoked medical educators to adopt tools where teaching and learning outcomes are effective. Availability of such research work kindled the author to compare the effectiveness of learning outcomes of technology-aided microanatomy teaching with age-old conventional teaching.

MATERIAL AND METHODS

This study protocol was conducted with the requirements of the reporting rules in the "Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines"[4] [Supplementary File 1-Figure 1] and strictly complied with its specifications. Since this work is a systematic review, the heterogeneity was present within the acceptable range, meta-analysis was performed.

Eligibility criteria

Criteria for included studies were defined as assessing learning outcome of histology teaching, that included both the theoretical and practical assessment among medical students. The full eligibility criteria are available in Table 1. The criteria for the inclusion included,

- Studies assessed the effectiveness of learning outcome in histology teaching
- Studies assessed the learning outcome in histology teaching between TAM and CT cohorts.

Search strategy

The electronic retrieval methods were adopted for the literature retrieval. A comprehensive and systematic research review using a combination of Medical Subject Headings (MeSH), controlled vocabulary, and keywords was conducted through various databases, including PubMed, SCOPUS, Cochrane, and Google Scholar for studies till June 2023. The full search strategy is available in Supplementary File 2-Table 1. Furthermore, a manual search of reference list of primary trials was conducted from the selected topics and relevant articles were included in the review and analysis.

Study selection

The search results were uploaded into the online systematic review program Covidence to conduct the study selection.[5,6] A two-stage screening process was conducted for study selection. The authors performed the literature search and screened the title, abstract, and keywords of all the studies. Screening of abstract and full text was done independently by the authors to select the studies that satisfy the eligibility criteria of this review. Any disagreements or discordances occurred during the entire selection process were resolved after the consultation with the senior author who supervised the meta-analysis (Dr. D.S). If conflicts arose between reviewers, the senior author (D.S) moderated a discussion to come to a joint decision.

Data extraction and management

The relevant study characteristics for the review were extracted by the authors independently related to outcome measures from the included studies. Data extraction was guided by a predetermined checklist with the first author's last name, published year, study design, learning outcome, and participants as medical students, as shown in Table 1.

Data were transferred (S.S., J.J.F.M) into the software Review Manager (RevMan_5.3, Copenhagen: The Nordic Cochrane Center, the Cochrane Collaboration, 2014) [24] Data entry was double-checked for correct entry through a comparison of data presented in the review and included the reports.

Outcome measure for the study

This was comparing conventional teaching and the impact of technology-aided histology teaching in enhancing the learning outcome of medical students.

Quality assessment

Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) was used to assess the risk of bias of the selected articles and the quality review process was monitored. Each article was categorized as follows: "low-risk," "moderate-risk," "serious-risk" and critical-risk of bias [Table 2].[7]

Statistical analysis

A comprehensive qualitative analysis was made. For quantitative meta-analysis, the binomial data were performed using RevMan_5.3.[8] When studies reported multiple arms in a single trial, only the relevant arms were included in the analysis. Due to heterogeneity among studies, a logistic-normal-random-effect model was conducted. The 95% confidence interval (CI) was performed for study-specific and overall pooled prevalence, respectively. To assess the heterogeny, I^2 statistics was used. Significant heterogeny was considered if $P < 0.05$ or $I^2 > 50\%$ among the studies.

Subgroup analysis was performed to assess the heterogeneity and potential confounding for studies. Study specific and

pooled estimates were graphically represented through forest plot for both combined and subgroup analysis. Publication bias was assessed and graphically represented by a funnel plot and asymmetry of the plot was tested using Egger's test. Sensitivity analysis was done to assess the reliability of the estimate obtained in the meta-analysis.

RESULTS

Study selection and characteristics

The initial search yielded 34 records, of which 12 articles underwent full-text evaluation, which identified five articles. A meta-analysis of five eligible comparative studies assessed the learning outcome by employing different teaching methods to teach histology for medical students. Meta-analysis involved 837 subjects who had technology-aided teaching methods and 1047 subjects who received traditional method of teaching (Control group) showed an overall significant effect in favor of control group (mean differences = 0.08, 95% CI 0.05–0.12, $P < 0.001$), as shown in Figure 1. A significant Q statistic ($P < 0.001$) indicated the presence of considerable heterogeneity ($I^2 = 100\%$) which could be due to varied demography and more recent studies.

Methodological quality of the included studies

The included five studies of the final review were all assessing the learning outcome of histology teaching methods among medical students. These articles were published between 2006 and 2022. All the included studies were non-randomized control trials (NRCTs).

DISCUSSION

Conventionally, in many medical colleges, the primary component of histology courses has involved the presentation of printed photo micrographic images of structures utilizing slides under microscopes. Students need a long time to learn the individual structures in a printed image because it takes longer to identify a single structure in a tissue when it is surrounded by numerous other structures, they are unfamiliar with. Introducing computer-assisted instruction is one solution to the problems. Students' learning experiences can be improved using computer technology to integrate written material, images, and animations.[3]

Overall, in the five studies included in this meta-analysis, we observed that traditional teaching blended with computer-assisted learning can improve the students' histology learning outcome. In terms of laboratory examination scores, our study findings did not appear to support the effectiveness of the method that used computer-assisted learning alone. This finding is parallel to Schmidt *et al*., who demonstrated that intelligent virtual microscopy facilitates self-directed learning and that blended learning can fulfill the individual needs of undergraduate medical students and support peer interactions without affecting practical skills.[9] The creation and use of an interactive virtual histology atlas for chiropractic students enhanced their performance in lab tests. The characteristics and utility of this atlas also met with the pupils' satisfaction. A comparison of the histology test results between the four lessons before and four lessons after the usage of the atlas enabled the evaluation of the atlas' utility. To rule out any discernible disparities in academic competency between the groups being examined, an analysis of admissions data was first conducted. This analysis included overall grade point average (GPA), science and non-science GPA, and a number of course units.[3]

Novel software program that uses annotated whole slide images in teaching normal histology can increase the test score of the students. Yohannan *et al*. showed virtual microscopic images as part of a blended instructional approach with traditional microscopy can give good results in the knowledge-based tests.[10] The authors of the above study took care of confounding factors in the form of cross-over study design and analysis of covariance in the data analysis and a large sample size. The limitation of this study includes a small number of virtual slides, short duration of study, and 2 time-collection of students' feedback. Regardless of the mode of evaluations, online self-directed learning modules in a mixed approach showed a considerable improvement in students' academic performance. When students' performance was evaluated using the virtual slide approach, there was a significant positive connection. However, adopting such module alone did not have a positive effect on learning outcomes. The authors declared the limitation of the study as the data presented for this study were gathered across several years at just one institution.[11] In contrast to the results of the present study, Cheng *et al*., showed that the test results for the flipped classroom participants were found to be significantly greater when compared to non-participants in the control group, suggesting that students may benefit from the flipped classroom format.[1] Subsequent questionnaires also revealed that the majority of the flipped classroom participants did relatively sincere preparations before class and engaged fully in classroom learning activities. This study has a few limitations which must be acknowledged. The study's first drawback is that it only included a limited sample of students, and the findings were extrapolated from a group of students who had only studied a short section of a comprehensive histology curriculum. In this study, each of the flipped classroom students were volunteers. It is also probable that the volunteers behaved more independently, preferred self-guided learning, and had higher levels of motivation which must have created potential biases.[1] Digitized microscopy images presented in dynamic format which considerably improved the practical histology scores as compared to static ones in remote histology learning.[12]

Table 1: Characteristics of the included studies.

First author	Year	Objective	Study duration	Study design	Intervention group	Control group	Results	Major limitation of the study
Cheng *et al.*[1]	2016	To compare the score of learners of flipped classroom and conventional histology learning	1 year	NRCT	Flipped class room learners	Conventional learners	Test score of participants in flipped classroom was significantly high on comparing conventional learner	Smaller sample size of interventional group Only a section of histology was compared
Goubran and Vinjamury[3]	2007	To compare the score of learners of interactive histology atlas with conventional learner	1 year	NRCT	Interactive histology atlas	Conventional learners	No significant difference was observed between the groups	Single centre Only 4 classes score was compared Not used for theoretical score comparison
Chimmalgi and Hortsch[11]	2022	Effectiveness of SDLM measured by traditional steeple-chase and virtual slide histology learning	3 years	NRCT	SDLM learner	Conventional learners	Blended learner had a significant learning outcome compared to standalone SDLM learners.	Single-center study, Students response not provide the exact role of SDLM
Yohannan *et al.*[10]	2019	Score of Virtual microscopy adjuvant Conventional learners compared with Conventional microscopy learners	1 year	NRCT	Virtual microscopy adjuvant traditional learner	Conventional learner	The score significantly improved in Interventional group	Single-center Only small number of slides were used
Mione *et al.*[12]	2016	Scores of dynamic and static histology images in histology learning	3 years	NRCT	Learning by Dynamic histology image	Learning by Static(Conventional) histology image	The test score of dynamic histology learners were significantly higher	Influencing factors like time usage and self-directed learning attitude of interventional group leaners was not measured.

SDLM: Self-directed learning modules, NRCT: Non-randomized control trial

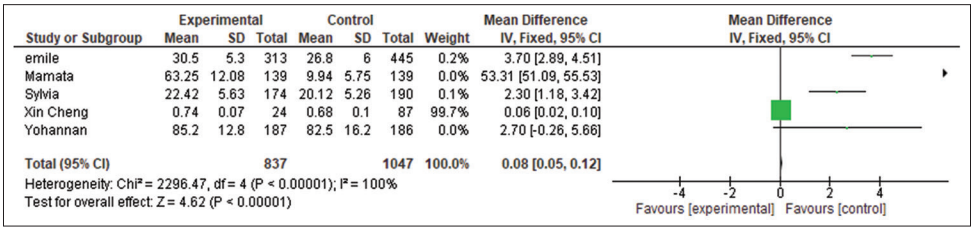

Figure 1: Forest plot of comparison: Traditional teaching versus traditional teaching blended with computer-assisted learning. SD: Standard deviation.

Table 2: Quality assessment of published articles by using ROBINS-I (Risk Of Bias In Non-randomized Studies of Interventions).

Year of publication	ROB_ Domain-1 (Bias due to confounding)	ROB_ Domain-2 (selection of participants into the study)	ROB_ Domain-3 (classification of interventions)	ROB_Domain-4 (Deviations from the intended interventions)	ROB_ Domain-5 (missing outcome data)	ROB_ Domain-6 (Measurement of outcome)	ROB_ Domain-7 (Selection of the reported result)	Overal ROB
2007								
2019								
2022								
2016								
2016								

ROB: Risk of Bias, Low risk is highlighted in green, Moderate risk is highlighted in yellow.

Limitations of the study

Despite the relevant information demonstrated above, this meta-analysis has its own limitations. As far as the lack of sufficient data with regards to complete histology curriculum, most studies that concerns the part of the histology, and hence they are susceptible to bias and confounding. The studies that used medical students, blended teaching, computer assisted learning were only reviewed which resulted in limited data. Most of the studies analysed in this review were non-randomised controlled trials with more number of participants in traditional group which must have overestimated the results in favour of the control group. Furthermore, due to smaller sample size in each study and single-centered studies, it cannot be extrapolated to the general studies.

CONCLUSION

Medical students must grasp fundamental histology to master more complex topics like histopathology. The introduction of computer-assisted learning in traditional teaching can be a great tool for better learning outcomes of the students in this era**.** This meta-analysis of published research studies demonstrates that traditional teaching gives promising results as compared to computer-assisted learning blended with traditional teaching. As a result, the authors states that though the students belong to the digital century they need traditional teaching for their academic performance. Further studies called for exploring the effect of teaching methods on the test score of the students in learning all portions of histology curriculum with a special focus on random sampling, adequate number of samples and confounding factors.

Authors' contributions

PN and SR had full access to all the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: PN and SR. Acquisition of data: PN and SR. Analysis or interpretation of data: JJ, SS. Drafting of the manuscript: PN and SR. Critical revision of the manuscript for important intellectual content: DS. Statistical analysis: JJ, SS. Administrative, technical, or material support: PN and SR. Supervision: DS.

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

Dr. Priyadharshini Nattalam Adikesavan, Dr. Reenaa Mohan and Dr. P. Sanjay are on the Editorial Board of the Journal.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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