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Original Article

Knowledge and Attitude Toward Therapeutic Drug Monitoring Among Undergraduate Medical Students: A Cross-Sectional Study

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ABSTRACT

Objectives: Therapeutic Drug Monitoring (TDM) is essential for optimizing drug therapy, especially in patients receiving medications with narrow therapeutic indices or those experiencing variable pharmacokinetics. The objective of this study was to assess the knowledge and attitude toward TDM among undergraduate medical students and to identify areas requiring curricular emphasis. Methods: A prospective cross-sectional study was conducted among 265 undergraduate medical students at KMCH Institute of Health Sciences & Research over a period of six months (February – June 2022). A self-administered structured questionnaire was distributed via Google Forms. The tool comprised three sections: demographic details, 20 knowledge-based questions, and 10 attitude-based questions related to TDM. Data were analysed using SPSS version 26. Descriptive statistics were expressed in terms of mean and proportions, while inferential statistics (independent t-test and one-way ANOVA) were used to compare knowledge scores across gender and academic years. Results: Of the 265 participants, 57% were female and 43% male, with representation across all years of study. A high percentage (89.1%) were aware of TDM, and 92.8% recognized its correlation with plasma drug levels and clinical outcomes. However, only 32.8% correctly identified the appropriate timing for plasma sample collection, and 55.8% were familiar with peak and trough levels. Most students held positive attitudes: 85.7% believed TDM improves treatment efficacy and safety, and 80.8% supported detailed TDM education for healthcare professionals. No statistically significant differences were observed in knowledge scores based on gender (p = 0.915) or academic year (p = 0.467). Conclusion: While overall awareness of TDM among undergraduate medical students was satisfactory, important knowledge gaps exist in clinical application, particularly in pharmacokinetic principles. The study underscores the need for incorporating structured TDM education into undergraduate curricula to promote rational prescribing and enhance therapeutic safety.

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Introduction

In order to guide dosage modifications and obtain the best possible therapeutic results, therapeutic drug monitoring, or TDM, is a clinical method that includes measuring drug concentrations, usually in blood or plasma. It is essential for tailoring pharmaceutical regimens, especially for patients at the age extremes, teenagers, those taking several drugs, or people with atypical pharmacokinetics because to physiological, environmental, or genetic factors [1]. Although blood and plasma are the main matrices, additional biological fluids like saliva, urine, perspiration, tears, and others can also be used for TDM. Measurements are made at predetermined intervals for some medications in order to maintain a steady and efficient bloodstream concentration, improving therapeutic efficacy and reducing toxicity. In order to achieve the best therapeutic effects, TDM relies on the proper timing and frequency of sample collection, precise analysis, and careful interpretation of data in light of clinical findings [2].

Drugs with a limited therapeutic range are the primary focus of therapeutic drug monitoring. Drugs with significant pharmacokinetic variability, those whose target concentrations are challenging to track, and those with a history of both beneficial and negative side effects are also monitored with this method [3]. After TDM, dose modifications may increase virological response rates or lessen drug-related toxicities. Digoxin (the therapeutic range is 0.8-2.0 µcg/L), theophylline (the therapeutic range for optimal bronchodilation is 10-20 mg/L), lithium (the optimal range for acute mania is 0.8-1.2 mmol/L), and phenytoin (the optimal range for anticonvulsant activity is 10-20 µcg/L) are among the medications that commonly require TDM. Achieving medical accuracy is the aim of TDM practice.

Drug monitoring pioneers in the 1970s concentrated on adverse drug reactions and made it abundantly evident that the prevalence of toxicity to medications like digoxin, phenytoin, lithium, and theophylline could be decreased by creating therapeutic ranges [4]. Vancomycin and β-lactam antibiotics are examples of antimicrobial medications whose dosage is directed by therapeutic drug monitoring, which helps to limit toxicity and maximize effectiveness. Antiretroviral therapy (ART) treatment results have been improved by the use of therapeutic drug monitoring (TDM)[5]. The use of therapeutic drug monitoring (TDM) as a means of optimizing treatment for inflammatory bowel disease (IBD) is growing. According to yet another observation, pulmonary toxicity is commonly seen in individuals receiving amiodarone treatment. To determine the risk of pulmonary toxicity, TDM of amiodarone and its active metabolite desethylamiodarone is available. TDM aids in the interpretation of clinical evidence of toxic or therapeutic effects, including nausea and vomiting, which can arise from both congestive heart failure and Digitalis toxicity [6].

The type of blood sample, the measuring method, the timing of blood collection, and the interpretation of data must all be carefully considered if measurements of plasma drug concentration are to be useful. First, a blood sample must be taken at the appropriate period after dosage in order to measure the drug concentration. Sampling for long-acting medications can be done right before the next dose using steady state blood levels. For short-acting medications, the post-abortive phase should begin 1-2 hours after oral or intramuscular dosage. Sampling should be carried out as soon as possible in poisoning situations and repeated periodically to gauge the harmful metabolite's elimination [7].

Any time can be used to sample blood in order to verify compliance. Similarly, loading dosages may be helpful in cases with poor therapeutic control, such as fast atrial fibrillation, in which case an immediate assay may be necessary. The dosing regimen's specifics (dose and duration) are crucial for interpreting the results [8]. In the past, a range of analytical techniques, from radioimmunoassay to high-performance liquid chromatography (HPLC) procedures, were used by drug testing labs to build their assay methodologies.

The two most often utilized methods are enzyme-linked immunosorbent assay (ELISA) and fluorescence polarization immunoassay (FPIA). TDM is an intervention technique that aims to reduce adverse drug reactions and enhance patient responses to critical life-sustaining medications [9].TDM is a suitable option for an economic outcome evaluation since the resources used by TDM techniques will probably be recovered by favourable results, such as fewer hospitalizations [10]. To increase future prescribers' awareness and comprehension, therapeutic drug monitoring has been included in medical undergraduate courses. Data on how well this knowledge translates into clinical readiness is still scarce, though. Therefore, the purpose of this study is to evaluate undergraduate medical students' understanding and awareness of therapeutic drug monitoring.

Materials and methods:

The present prospective cross-sectional study was conducted to assess the knowledge and attitude regarding Therapeutic Drug Monitoring (TDM) among undergraduate medical students at KMCH Institute of Health Sciences & Research over a period of six months, from February to June 2022. The study population comprised undergraduate medical students of both genders who were willing to participate, while those unwilling to participate were excluded. A convenient sampling method was employed to recruit participants. Following approval from the Institutional Human Ethics Committee, data collection was carried out using a self-administered, structured questionnaire distributed via Google Forms.

The questionnaire consisted of three sections: Section A collected demographic information such as age, gender, and qualification; Section B included twenty questions assessing the participants' knowledge of TDM; and Section C comprised ten items evaluating their attitude towards TDM. A brief description of the study's purpose and a statement of voluntary participation were included at the beginning of the online form. While informed consent was waived, ethical considerations regarding participant confidentiality and voluntary participation were addressed and documented in the ethics submission.

Statistical analysis:

The collected data were analyzed using SPSS software version 26. Descriptive statistics such as mean and proportions were used to summarize the data. Additionally, each question's maximum and minimum response values were analyzed separately to identify trends and variability in knowledge and attitude among the participants.

Results

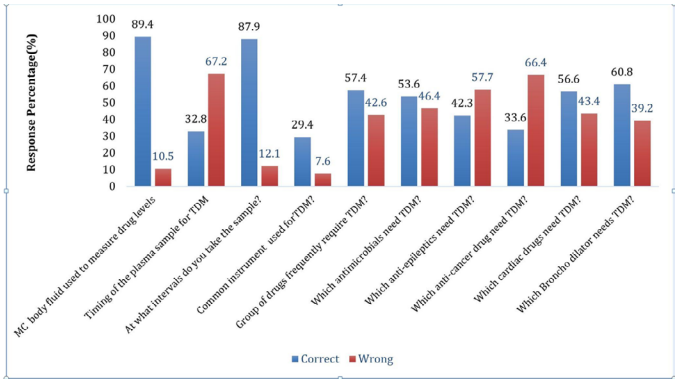
A total of 265 undergraduate medical students participated in the study. The distribution of the study population by gender revealed that 151 participants (57.0%) were female and 114 (43.0%) were male. Regarding their academic year, 48 students (18.1%) were from the first year, 63 (23.8%) from the second year, 75 (28.3%) from the third year, and 79 (29.8%) from the final year.

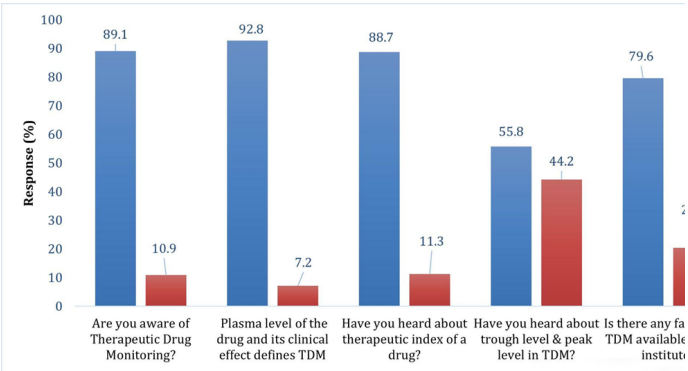
In the knowledge-based section, a majority of students demonstrated awareness of Therapeutic Drug Monitoring (TDM), with 89.1% affirming familiarity with the concept. A similar trend was observed in their understanding of the relationship between plasma drug levels and clinical effects (92.8%) and knowledge of the therapeutic index (88.7%). However, awareness was comparatively lower for specific concepts like "peak" and "trough" levels (55.8%) and the timing of plasma sampling (32.8%). Most participants correctly identified blood as the most commonly used fluid for TDM (89.4%), and 87.9% were aware that samples should be taken at specific intervals. Regarding instruments used for TDM, 70.6% correctly identified high-performance instruments such as HPLC.

Participants showed a moderate understanding of pharmacokinetic variability, with a wide distribution of responses across multiple options, indicating partial knowledge. When asked about scenarios where TDM is useful, only 44.9% responded correctly, while responses to drug classes requiring TDM varied—majority correctly identified antimicrobials (54.0%), antiepileptics (57.7%), anticancer agents (66.4%), cardiac drugs (56.6%), and bronchodilators (60.8%) as relevant drug groups (Figure 1&2).

In the attitude-based section, most participants believed that TDM is necessary (85.7%) and helps in improving efficacy and reducing adverse effects (85.7%).

Figure 1 & 2: Knowledge of students towards Therapeutic Drug monitoring





A significant proportion (73.2%) felt that TDM should be part of the undergraduate curriculum, and 80.8% believed it should be taught in detail to healthcare professionals. However, responses to whether TDM is time-consuming for clinicians were divided: 43% disagreed, 36.2% agreed, and 20.8% were neutral. About 57% considered TDM a professional obligation, while 35.5% believed it adds economic burden to patients. Over half (55.1%) agreed that food can interfere with drug levels, and 48.3% considered TDM feasible as a bedside test. [Table 1].

Table 1 : Attitude of students towards Therapeutic Drug monitoring

S.No	Parameters	Yes (%)	No (%)	May be (%)
1	Do you think measuring of Therapeutic Drug Monitoring (TDM) is necessary?	85.7	3.8	10
2	TDM helps in maximizing clinical efficacy and minimizing adverse effects of drugs	85.7	5.7	8.7
3	Do you think it is necessary to include Therapeutic Drug Monitoring (TDM) Undergraduate level?	73.2	7.2	19.6
4	Do you think that Therapeutic Drug Monitoring (TDM)should be taught in detail to healthcare professionals?	80.8	5.3	14
5	Rather than being beneficial to the patients, it is time consuming for busy clinicians	43	20.8	36.2
6	Do you think Therapeutic Drug Monitoring is a professional obligation for you?	57	18.5	24.5
7	Conducting TDM simply causes economic burden to the patient	37.4	27.2	35.5
8	Do you think food interferes with TDM level?	55.1	12.1	32.8
9	TDM can be used as a bedside investigation	48.3	16.2	35.5
10	Is it necessary to have a TDM centre in all institutes?	89.4	10.6	0

Institutional practices and infrastructure were also assessed. About 79.6% of students reported the presence of TDM facilities in their institute, and 89.4% felt that every institute should have a TDM centre. Regarding their opinion on establishing TDM centres in hospitals, more than half (56.2%) believed it should be implemented in every hospital, while others suggested it should depend on hospital size (23.4%) or that one centre per city would be sufficient (6.0%).

Statistical analysis using independent t-tests revealed no significant gender-based difference in knowledge scores ($p = 0.915$). Further comparison using one-way ANOVA across the different academic years showed no statistically significant difference in knowledge scores among the four groups ($p = 0.467$), indicating relatively uniform awareness levels across years.

Discussion

Therapeutic Drug Monitoring (TDM) plays a pivotal role in optimizing pharmacotherapy, particularly for drugs with narrow therapeutic indices and significant pharmacokinetic variability. It serves as a cornerstone in precision medicine and safe prescribing practices, making it essential for future clinicians to be well-versed in its principles. The present study aimed to assess the level of awareness and attitude toward TDM among undergraduate medical students, an area that remains underexplored in the Indian medical education context.

Of the 265 undergraduate students that took part in the current study, somewhat more were female (57.0%) than male (43.0%). A representative sample of the undergraduate cohort was guaranteed by the distribution across all academic years. According to the overall knowledge ratings, pupils had a solid foundational understanding of TDM concepts. It is promising that over 85% of students showed knowledge of TDM and its clinical importance. This result is in line with a study conducted in Nepal by Shakya et al. (2015), which found that more than 80% of pharmacy students understood the fundamentals of TDM and how it functions in clinical decision-making [11].

However, understanding levels decreased when it came to more complex ideas like pharmacokinetic variability, peak and trough levels, and sample collection time; only 55.8%, 32.8%, and 32.5% of students correctly answered these questions, respectively.

These knowledge gaps are consistent with the findings of Vora et al. (2020), who found that although students frequently understood the theoretical components of TDM, they had little comprehension of its practical applications, such as when to sample and how to identify influencing factors [12]. In line with our finding that only 44.9% of students could correctly identify clinical scenarios requiring TDM use [13], another study by Hirapara et al. (2017) similarly highlighted the low understanding among medical students about the clinical interpretation of TDM results. With more than 50% of students correctly answering, knowledge of the particular drug classes requiring TDM—such as antimicrobials, antiepileptics, and cardiac drugs—was comparatively better in our study. This conclusion is consistent with a study by Khan et al. (2018) that found students had comparable awareness levels for medicines like lithium, vancomycin, and phenytoin that are often monitored [14]. Nonetheless, the uneven understanding of medications like bronchodilators and anti-cancer treatments suggests that pharmacology courses need to place more of an emphasis on them.

Students tended to have a good attitude toward TDM. According to the results of a Nigerian study by Erah et al. (2006), where students showed a strong appreciation for the clinical utility of TDM in improving patient safety [15], the vast majority of respondents thought that TDM helped

maximize therapeutic efficacy and minimize adverse drug reactions. According to our study, 73.2% of students approved TDM's inclusion at the undergraduate level, and 80.8% of students supported its extensive instruction for medical professionals. These numbers support the WHO's recommendations for integrating rational drug use and monitoring principles into medical education and indicate that students are becoming more aware of the importance of TDM in modern clinical practice [16].

Nonetheless, there was still considerable doubt about TDM's viability in practice. About 35.5% of students voiced concerns about the financial strain, and 36.2% thought it took a lot of time. Izzedine et al. (2013) have brought attention to these issues, pointing out that TDM's expense and logistical needs can serve as disincentives, especially in environments with limited resources [17]. However, 56.2% of our participants supported TDM centers in all hospitals, demonstrating their conviction in the service's long-term clinical worth.

It's interesting to note that there were no discernible variations in knowledge scores by academic year or gender. This conclusion runs counter to research like that of Badyal and Desai (2014), who found that students' knowledge of pharmacology improved as they progressed through their academic careers, perhaps as a result of more extensive clinical experience [18]. Our study's lack of a statistically significant difference could indicate that TDM principles are not regularly incorporated into the curriculum or are just briefly covered in each year.

Overall, the results indicate that undergraduate programs that emphasize practical clinical pharmacology, especially TDM modules, urgently need to improve their pharmacology instruction. As evidenced by research from western curricula where such interventions dramatically enhanced students' clinical reasoning regarding drug monitoring, incorporating case-based learning, simulations, and interactive workshops may increase knowledge and implementation [19,20].

Conclusion

The study reveals a moderate to high awareness of basic TDM principles among undergraduate medical students, but highlights key knowledge gaps in clinical application and pharmacokinetic principles. The generally positive attitude among students suggests a readiness to engage more deeply with the subject, provided adequate curricular support is offered. To build competence in rational drug use and safe prescribing, medical educators must consider integrating structured TDM teaching early in the curriculum.

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