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Divergent Trends: Projecting the Prevalence of Liver Cancer in Afghanistan and Globally, 2021–2040

Mahdi Fakhar, *Meysam Olfatifar

Gastroenterology and Hepatology Diseases Research Center, Qom University of Medical Sciences, Qom, Iran

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*Corresponding Author:
Meysam Olfatifar

E-mail address:
ol.meysam92@gmail.com

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ABSTRACT

Background: Liver cancer is an important global health problem with a pronounced epidemiological pattern between nations. Understanding the future epidemiological picture through a robust forecasting model is essential for effective public health planning. We aimed to estimate the future prevalence of liver cancer in Afghanistan by 2040 using the Illness Death Model (IDM).

Methods: This study utilized the IDM and calibrated it based on Global Burden of Disease (GBD) data from 1990 to 2021 to estimate age-standardized prevalence rates (ASPR) for liver cancer in Afghanistan and worldwide from 2021 to 2040. Our analysis included sex-disaggregated data to provide a more comprehensive understanding of the disease's impact.

Results: Projections reveal divergent trajectories: global ASPR is expected to decline by 25.0%, while Afghanistan may experience a 17.0% increase. Sex-specific analysis shows Afghan women facing the most substantial burden with a projected 21.3% increase in ASPR, compared to a 12.6% increase among Afghan men. These trends contrast sharply with global patterns where both sexes show declining prevalence.

Conclusion: The divergent epidemiological trajectories of liver cancer prevalence between Afghanistan and global can underscore the importance of context-specific public health strategies in resource-limited settings. So that, enhanced vaccination programs, improved food safety regulations, and strengthened healthcare infrastructure are critical for addressing Afghanistan's growing liver cancer burden.

Keywords: Liver cancer; Age-standardized prevalence rate; Disease burden forecasting; Epidemiological transition

Introduction

Liver cancer constitutes a complex and escalating global health crisis, marked by elevated mortality [1], and complex multifactorial causation [2]. Recent evidence shows the profound geographical disparities in disease burden, wherein resource-limited and conflict-affected regions endure disproportionately high incidence and mortality rates. [3]. In 2021, Afghanistan faced a significant public health challenge with liver cancer [4], exhibiting prevalence and incidence rates of 7.12 and 6.24 per 100,000 people, respectively [5]. Effective disease management and prevention require understanding disease

epidemiology to develop public health interventions that reduce disease burden. However, resource-limited settings like Afghanistan often lack valid and specific data.

A growing body of literature employs statistical models, such as illness-death models (IDM) with Global Burden of Disease (GBD) data, to project cancer prevalence and evaluate the potential impact of public health intervention [6, 7]. However, these models are often applied to regions with stable data infrastructure, creating a significant knowledge gap for nations like Afghanistan. Afghanistan's unique epidemiology—characterized by high rates of hepatitis, evolving healthcare access, and country-specific risk factors—means that global or regional models cannot accurately reflect its future disease burden. Our study addresses this gap by developing a tailored prevalence prediction model for liver cancer in Afghanistan. This country-specific focus is crucial to provide health policymakers with actionable data for resource allocation, targeted prevention programs, and strategic planning tailored to the local context [8, 9].

While global liver cancer trends are studied [6, 7], country-specific forecasts for Afghanistan are lacking. Our research addresses this gap by predicting the prevalence of liver cancer in Afghanistan from 2021 to 2040 using GBD data, providing crucial information for national health policymakers. This study have used the IDM, which considers the interrelationship between epidemiological indicators, and provides a future outlook for liver cancer by considering gender data. Our findings are expected to provide evidence that can guide health managers and facilitate the development of targeted interventions aimed at curbing the growing trend of liver cancer in Afghanistan.

Methods

Data Sources

To estimate the future burden of liver cancer, epidemiological data were retrieved from the Global Burden of Disease Study 2021 (GBD 2021), which is accessible through the Global Health Data Exchange repository (https://vizhub.healthdata.org/gbd-results/).The dataset encompassed sex-disaggregated and age-standardized metrics for liver cancer incidence, prevalence, and cause-specific mortality in Afghanistan spanning the period from 1990 to 2021. Supplementary demographic information necessary for population-based forecasting, were acquired from the GHDx population projection platform (https://vizhub.healthdata.org/population-forecast/).

Modeling Approach

We implemented a discrete-time IDM, a compartmental structure simulating transitions between three core states: Susceptible (S), Diseased (D), and Death. The model simulated a closed population with no migration, where individuals transitioned from susceptible to diseased based on constant, sex-specific incidence rates, and from Diseased to Death due to disease-attributable mortality; remission was not considered, consistent with the chronic nature of liver cancer. The dynamic transitions over discrete time steps were defined by a system of difference equations, with the full mathematical formulation detailed in reference [10]. We calibrated the model using historical GBD data from 1990 to 2021, employing Root Mean Square Error (RMSE) minimization to align model predictions with observed values. This calibrated approach enabled us to generate nationally and globally representative annual liver cancer prevalence projections for Afghanistan through 2040, capturing key sex-specific epidemiological differences in the natural history from susceptibility to active disease and subsequent mortality.

Results

Historical (1990 to 2021) and projected (from 2022 to 2040) patterns

Worldwide ASPR Patterns

From 1990 to 2021, the liver cancer ASPR at global level showed an 11.867% increase among both sexes and reached 8.68 cases per 100,000 population in 2021, with sex specified figures of 4.95 for females and 12.76 for males (Figure 1). Moreover, the model projects a reversal of this trend by 2040, with an overall reduction of 25.004%, resulting in an ASPR of 6.51 (95% CI: 6.08-6.97) for both sexes. Among females, prevalence is forecasted to diminish by 22.858% to 3.821 (95% CI: 3.67-3.98), while male ASPR is expected to decline by 25.117% to 9.557 (95% CI: 8.83-10.34) (Table 1 and Figure 1).

Afghanistan ASPR Patterns

Between 1990 to 2021, Afghanistan showed a 6.033% decrease in liver cancer prevalence for both sexes. By 2021, the ASPR was 7.12 per 100,000, that was substantially elevated among females (8.47) relative to males (5.70). Projections for 2040 indicate an increasing trend, characterized by a 17.007% increase in overall prevalence and an ASPR of 8.334 (95% CI: 7.87-8.82). Gender-specific forecasts predict a 21.341% rise for females (reaching 10.278) and a 12.609% increase for males (reaching 6.422) (Table 1 and Figure 1).

Comparative Analysis of Global and Afghan Trajectories

We observed fundamentally divergent trends between global and Afghanistan's GBD data from 1990 to 2021 so that globally we observe an increase of 11.867% versus Afghanistan's decrease of 6.033%. Although, the baseline ASPR in 2021 was nearly higher globally (8.68) compared to Afghanistan (7.12). By 2040 our results demonstrate opposing directions: global ASPR is anticipated to decline markedly by 25.005%, while Afghanistan is expected to experience a considerable increase of 17.001%. This disparity is especially evident among female populations, with Afghan women projected to experience a 21.341% increase against a 22.858% global decrease (Table 1 and Figure 1). These contrasting patterns suggest potentially distinctive risk factor evolution, diagnostic capacity limitations, or healthcare system challenges in Afghanistan that deviate from worldwide patterns.

Table 1: Projected age-standardized prevalence rate (ASPR) of liver cancer globally and in Afghanistan in five-year intervals from 2022 to 2040 and two corresponding percentage change (%)

Sex	*Region/country*	*2022*	*2025*	*2030*	*2035*	*2040*	*Percent change 1990 vs. 2021*	*Percent change 2021 vs. 2040*
Both	Global	8.486(8.38-8.6)	8.119(7.95-8.3)	7.543(7.27-7.83)	7.008(6.65-7.38)	6.51(6.08-6.97)	11.867	-25.004
	Afghanistan	7.211(7.13-7.29)	7.387(7.25-7.52)	7.69(7.45-7.93)	8.006(7.66-8.37)	8.334(7.87-8.82)	-6.033	17.007
Female	Global	4.86(4.82-4.9)	4.669(4.61-4.73)	4.367(4.27-4.47)	4.085(3.96-4.22)	3.821(3.67-3.98)	5.645	-22.858
	Afghanistan	8.604(8.51-8.7)	8.863(8.7-9.03)	9.311(9.01-9.62)	9.783(9.34-10.24)	10.278(9.68-10.91)	-2.989	21.341
Male	Global	12.46(12.27-12.65)	11.921(11.62-12.23)	11.074(10.61-11.56)	10.287(9.68-10.94)	9.557(8.83-10.34)	15.688	-25.117
	Afghanistan	5.759(5.69-5.83)	5.864(5.75-5.98)	6.044(5.85-6.25)	6.23(5.94-6.53)	6.422(6.04-6.83)	-10.946	12.609

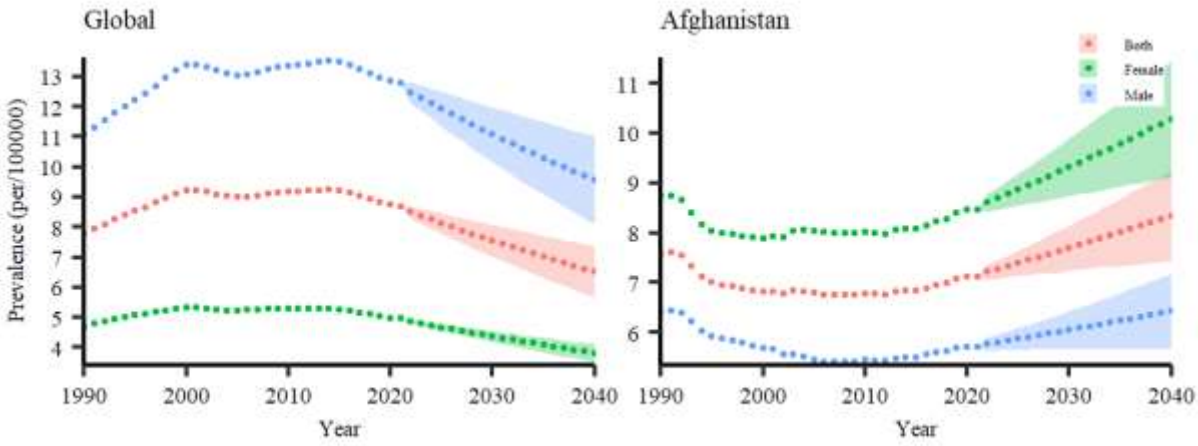

Figure 1: Observed and projected age-standardized prevalence rate (ASPR) of liver cancer, globally and in Afghanistan, 1990-2040

Discussion

This investigation sought to forecast the epidemiological trajectory of liver cancer prevalence in Afghanistan within the global context from 2021 to 2040. Our findings demonstrate a remarkable epidemiological divergence: global ASPR projections indicate a substantial 25.0% reduction, whereas Afghanistan is anticipated to experience a concerning 17.0% elevation, with particularly pronounced increases among female populations (21.3%). This reversal of previous favorable trends observed between 1990-2021, during which Afghanistan achieved a 6.0% decline, underscores a significant public health challenge. Afghanistan's liver cancer burden is intensifying despite worldwide improvements, potentially attributable to persistent deficiencies in risk factor management, healthcare accessibility, and fundamental public health infrastructure [1]. In countries with robust public health infrastructure, such as China, documented declines in liver cancer incidence may be associated with specific public health measures. These include the implementation of hepatitis B immunization programs [12] and the establishment of food safety regulations to reduce aflatoxin exposure [13]. The success of these combined strategies in such settings provides a compelling model for their potential efficacy [14, 15].

The observed disparity in sex-specific disease burden is profound: while global trends show a reduction in the ASPR for women (-22.9%), our model projects a 21.3% increase for Afghan women. This divergence likely stems from a complex interplay of factors specific to the Afghan context. First, epidemiological patterns of key risk factors, such as chronic hepatitis B and C infection, may exhibit distinct gender distributions in the region, though data are often limited. Second, and likely more critical, are the profound sociocultural and economic barriers to healthcare access that differentially impact women. These barriers including financial dependence, restricted mobility, and gender norms that prioritize male health can lead to significant delays in diagnosis, resulting in more advanced disease stages at presentation and consequently higher measured prevalence. Third, significant under-ascertainment in cancer registries may bias reporting, particularly for women in settings where healthcare-seeking behavior is heavily constrained.

Future research is essential to investigate these hypotheses through targeted seroprevalence surveys and qualitative studies on healthcare-seeking behavior to better elucidate the multifactorial

origins of this disparity. This finding is inconsistent with other studies conducted in comparable settings. For instance, research in Pakistan has documented elevated liver cancer prevalence and mortality rates in male populations compared to females [16], a discrepancy that requires further investigation. Moreover, Afghanistan's projected epidemiological pattern aligns with that of neighboring countries. For instance, Iran has experienced increasing liver cancer rates even with more advanced surveillance and management systems [17]. This similarity underscores the importance of strengthening public health initiatives in Afghanistan to address the rising burden of liver cancer effectively. However, this suggests that Afghanistan's challenges extend beyond insufficient screening programs, inadequate vaccination coverage, and limited cancer treatment infrastructure. It also suggests a potential geographical or genetic predisposition that may help to justify this epidemiological pattern.

Strengths and Limitations

This study demonstrates several methodological advantages, particularly the application of IDM to generate long-term projections—an approach that incorporates complex dynamic interactions between epidemiological indices [10]. To our knowledge, this study represents the first modeling effort to project the future burden of liver cancer specifically for Afghanistan, thereby addressing a critical gap in the existing literature largely focused on regional or global estimates. The integration of sex-disaggregated data further enhances the policy relevance of our findings for targeted intervention. This study is subject to several important limitations, primarily arising from the data-scarce context of Afghanistan. The projections are inherently dependent on historical GBD data that are likely incomplete due to well-documented deficiencies in Afghanistan's healthcare information systems, particularly during prolonged periods of armed conflict which disrupt data collection and reporting [18-20]. This underlying data constraint means that the model's baseline may not fully capture the true historical disease burden and introduces potential error when extrapolating these inputs into future projections. A direct consequence of this is the difficulty, or impossibility, of robustly validating the model against comprehensive historical records, a standard practice in data-rich settings. These compounded shortcomings data incompleteness and an inability to validate are reflected in the substantial uncertainty of our forecasts, as evidenced by the wider confidence intervals for Afghan projections compared to global estimates. Therefore, the point estimates should be interpreted not as precise predictions, but as plausible projections within a range of possible outcomes that are heavily contingent on the quality and continuity of the imperfect underlying data.

Conclusion

Our projections indicate an urgent need for targeted interventions to address the escalating burden of liver cancer in Afghanistan. Under current support levels, this trend is set to rise, necessitating a decisive shift in policy towards expanding hepatitis B vaccination initiatives, enforcing food safety regulations to reduce aflatoxin exposure, and strengthening early cancer detection capabilities. To ensure these actions are effective, future efforts must address the critical limitation of incomplete local data by investing in robust cancer registration systems. Furthermore, subsequent research should prioritize the empirical validation of these projections and investigate cost-effective prevention strategies tailored to Afghanistan's resource-limited context.

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Conflict of interest

The authors declare that there is no conflict of interests.

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