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Chronic kidney disease is the major cause of death in Uddanam: A population-representative study using Smart Verbal Autopsy

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Running title: Cause of death assessment in Uddanam using SmartVA

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Abstract

Introduction: Uddanam is an agricultural area with a high burden of chronic kidney disease of unknown aetiology (CKDu). Despite reports of many deaths due to CKD in the lay press, the exact contribution of CKD to deaths remains uncertain as most deaths occur outside medical care.

Methods: We used SmartVA automated verbal autopsy (VA) tool to ascertain the cause-specific mortality fractions amongst a 2419 subject-strong general population cohort in Uddanam between 2018-2022. VA interviews were conducted twice with the family members of the deceased.

Results: A total of 133 deaths were recorded, giving a crude death rate of 5.5%, 10 times higher than that recorded in national surveys. CKD was responsible for 45% of all deaths, followed by ischemic heart disease (15%) and respiratory disease (6%).

Conclusion: This study confirms CKD as the leading cause of mortality in this high CKD burden area and provides crucial data for public health decision-making and resource allocation.

Keywords

Chronic kidney disease, CKD of unknown etiology, Cause of Death, Verbal autopsy, SmartVA

Introduction

Chronic kidney disease (CKD) is the 3rd fastest growing cause of death worldwide and is projected to rise the rank of causes of death (COD) from 16th in 2016 to 5th by 2040[1] . The greatest increases in CKD deaths are forecast in low and lower-middle-income countries. India has seen a 50% increase in the contribution of CKD of all deaths in 15 to 69-year-olds from 2001-03 to 2011-13[2]. COD reporting is problematic in many jurisdictions, including India, and the global burden of disease (GBD) has admitted to having a high proportion of garbage codes (codes that are not useful for public health analysis) in ascertaining a CKD diagnosis[3]. Many deaths occur at home for which the cause of death is either not reported at all or reported by untrained persons[4]. Only 22.3% of the total registered deaths in 2020 were medically certified[4]. Therefore, the true contribution of various conditions to deaths remains uncertain. Tools like verbal autopsy have been used to reduce this uncertainty[5].

Population clusters with higher than usual prevalence of CKD not associated with traditional risk factors such as diabetes, hypertension, and other known etiological categories have been reported in many parts of the world. This chronic kidney disease of unknown origin (CKDu), is mostly encountered amongst rural agricultural communities[6]. One such region is in the coastal district of Srikakulam in Andhra Pradesh, India, known as Uddanam (population 5.5 million)[7]. The age and sex-adjusted prevalence of CKD in this area is estimated at 18-22%[8,10], 2.5 to 3.3 times higher than the population prevalence of CKD reported from other regions of India[9].

More than 4500 deaths due to kidney disease were reported in Uddanam in the lay press in 2015[10]. However, there has been no formal ascertainment of the cause of death in this population, critical for gaining actionable insights. We conducted this study to ascertain the cause-specific mortality fractions to overcome the key data gap in COD estimates using the SmartVA automated verbal autopsy (VA) tool[11] in a population-based cohort of adults in Uddanam.

Methods

This population-representative study was conducted in Uddanam as a part of an ongoing research program, the Study to Test and Operationalize Preventive Approaches for Chronic Kidney Disease of Undetermined Etiology (STOPCKDu), the details of which are published elsewhere8,12. The study established a general population-based cohort in July 2018 using a cluster sample technique, and the participants are being followed up to determine the incidence and risk factors for kidney disease progression.

All households included in the study were surveyed between 2018 and 2022 to create a mortality list through active community surveillance. After obtaining verbal consent from the family members, health workers scheduled an appointment for a VA interview. The primary informants for the interviews were the deceased's closest relatives. The George Institute Ethics Committee approved the study.

We used the Smart Verbal Autopsy (SmartVA), a computerized algorithm validated by Population Health Metrics and Research Consortium in various settings and included in WHO 2022 questionnaire. The tool has been developed to interpret data from interviews conducted with family members or caregivers of a deceased individual using a set of standardized questions to collect information about the signs, symptoms, and circumstances of the individual's death and applies an automated algorithm to assign a probable cause of death based on the collected data[13,16] . There are three age-specific modules and a general information module in the Smart VA questionnaire: neonatal fatalities (from birth to 28 days), child deaths (from 29 days up to 11 years), & adult deaths (from 12 years on). We used the adult deaths module for this study. The general information module collects data about the decedent's demographic details, education, household characteristics, and a list of their occupants. The adult module gathers information on the deceased's symptoms, past medical history, lifestyle

(smoking and alcohol intake), injuries, and women's health issues if the deceased were a female. Additionally, it transcribes data from death certificates and available medical records. We used modified Kuppuswamy scale to assess the socioeconomic status (SES) of the participants (Supplementary File). This scale considers three key parameters: the education and occupation of the participant, as well as the total income derived from all sources within the family.

Verbal autopsy interview and quality maintenance

A trained interviewer collected data on Android phones using a questionnaire developed by the Population Health Metrics and Research Consortium (PHMRC), translated into local language (Telugu) and implemented with the Open Data Kit (ODK) software suite[17].

Household members (aged 18 and up) who had cared for the deceased or were familiar with the illness were interviewed in person. If medical records were accessible, the interviewer was asked to provide a transcription of the medical record's most recent summary. If a death certificate was provided, the interviewer was asked to note the reason for death as listed on the certificate.

Interviews lasted an average of 25 to 30 minutes, with a further 3–5 min required for the open narrative section. The completed questionnaires were saved on the tablets and transmitted to a central database following verification. To ensure the highest quality data was collected, this questionnaire was administered twice over three months by two independent, trained interviewers.

Data analysis

The data were exported from ODK Collect using the ODK Briefcase tool as Comma Separated Value (CSV) files and uploaded into the SmartVA program which assigns individual COD by using the Tariff Method 2.0 method,[14,17] which uses an additive algorithm that assigning weights or scores to symptoms and signs reported during a verbal autopsy interview. These scores are based on their associations with different causes of death. The cumulative score for a particular set of symptoms and signs helps determine the most likely cause of death for the individual. In the few instances where

symptoms were vague, contradictory, or mutually inconsistent, Smart VA could not determine the cause of death, and as a result, these deaths were deemed undetermined. Cohen's kappa statistic (κ) was used to compare the agreement proportions between interviews.

Cause of death assignment

If the SmartVA-generated CoD assignment matched between the two interviewers, it was considered the final CoD. All unmatched results were reviewed by a trained, unbiased physician who had access to the decedent's VA narratives and medical records. Assessment of the physician was considered the final cause of death in the case of unmatched records (Figure 1).

Results

The STOP-CKDu cohort consisted of 2419 participants (Table 1). During a median follow-up of 3.9 years, there were 133 deaths (crude death rate 5.5%). A total of 100 (85.2%) were males, and 90 (67.7%) belonged to the lower-middle socio-economic group. The median (IQR) age at death in the sample was 56 (48 - 66) and 55 (47 - 60) years for males and females, respectively. A total of 106 deaths were reported at home; the number was higher among females (87.9%) than males (77%). Cause specific mortality fraction from the STOP-CKDu cohort and GBD estimates are depicted in figure 1. CKD and chronic respiratory diseases are more prevalent in the study population, while burden of deaths due to neoplasm and TB is higher at the national level. Age specific death rates from the STOP-CKDu cohort compared with vital statistics death rate of Andhra Pradesh are summarised in Supplementary Table 1. There was a high level of agreement between the COD determined in the two independent interviews (86.5%), with a Cohen's kappa (κ) statistic score of 0.85.

The 15 leading COD by sex, before and after re-distribution of undetermined causes, are reported in Table 2. Tariff assigned a specific COD for 94.7% of deaths, with the COD being undetermined in approximately 5.3% of cases. The leading COD was CKD in 60 (45.1%), followed by ischemic heart

disease (20, 15%), respiratory disease (8, 6%), and stroke (7, 5.3%). The COD distribution was similar between males and females.

Discussion

This first-of-its-kind study confirms CKD as the dominant COD amongst this rural agricultural population, long identified as a high CKD prevalence area. The proportion of individuals with CKD as the COD was significantly greater than that reported from the GBD estimates for the state. Also, the annual all-cause and sex-specific mortality rates were nearly ten times higher than that documented in the sample registration survey report for Andhra Pradesh[18] among adults of age 20 years and above. The COD ascertainment was made with high confidence as data was collected twice by independent interviewers, and any disagreements resolved by an independent physician.

Our study showed an alarmingly high proportion of CKD deaths in this community. The burden of CKD mortality is more than the national and state average (2.37% and 2.08% of total deaths, respectively), and the neighbouring states that report CKDu clusters, such as Tamil Nadu (5.16%), Kerala (4.89%), Goa (3.66%), and West Bengal (2.97%). The high burden of CKD deaths could be related to poor access to care pathways[19].

High mortality burden among communities with high CKDu burden is also reported from Central America (60-70/100,000 population)[20,21] and Sri Lanka (67.6% of total deaths)[22]. This high burden of CKD cases and associated mortality underscore the need for systematic efforts to establish the cause of CKDu and generate evidence on locally acceptable and scalable primary and secondary preventative strategies.

We used an automated tool for COD assessment i.e., SmartVA. High reliability scores for COD ascertainment were observed from existing studies using similar tools in community settings of Uganda[23], Indonesia[24], China [25], and Philippines [26]. Our finding of favourable agreement scores, the minimal proportion of undermined deaths, and low disagreement rate between the two interviewers

indicate SmartVA can generate high-quality VA data in rural settings and has the potential to be used as tool for medical certification of deaths in community settings[27]. These findings have implications for improving the quality of death reporting from rural communities which is vital for developing meaningful policies.

Working collaboratively with trained staff and supplementing the cause of death results with adjudication from an independent physician are the principal strengths of our work. The proportion of undetermined deaths was minimal, indicating a high quality of verbal autopsy narratives, which was achieved by adequately training the investigators, utilizing medical records, and using an automated VA method. The limitations include the lack of a comparator for verbal autopsy records collected solely by the SmartVA tool. The delay between the time of death and verbal autopsy interviews might have introduced a recall bias, especially where the interval was relatively long. Also, given that CKD is endemic in the region, the families could have inappropriately attributed the deaths to CKD. The latter was minimized by collecting comprehensive medical information, verifying the informant's narratives with medical records, and conducting the interviews twice by independent interviewers. Thirdly, our study was not powered enough to estimate any association or generate a hypothesis of no causal inference, so these findings should be confirmed in larger studies. Lastly, factors associated with lower mortality rates for deaths attributable to tuberculosis and neoplasm in STOP-CKDu cohorts need to be explored further.

In conclusion, using a validated automated VA tool, this population-based study provides accurate information on cause-specific mortality rates for the adult population of the Uddanam region. The burden of mortality attributable to CKD is high, which indicates that policymakers need to address this concern and develop region-specific policies to prevent and manage CKD through prompt and accurate screening and diagnosis of CKD cases. Equally important would also be to act on improving community awareness of the significance of early diagnosis and management.

Disclosures:

VJ has received grant funding from GSK, Baxter Healthcare, and Biocon and honoraria from Bayer, AstraZeneca, Boehringer Ingelheim, NephroPlus, and Zydus Cadilla, under the policy of all honoraria being paid to the organization.

Supplementary file:

1) Supplementary Figure 1: Data collection flow
2) Supplementary table S1: Age and sex disaggregated mortality data of Andhra Pradesh and STOP CKDu study.
3) PHMRC General module
4) PHMRC shortened verbal autopsy questionnaire adult verbal autopsy module.
5) Modified kuppuswamy classification, socio economic status scale.

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Figure Legends

Figure 1: Cause-specific mortality fractions for leading causes of death from verbal autopsy data in the STOP CKDu cohort, Uddanam region (n=133) compared with Global Burden of Disease estimates for India (age >20 years)

275 **Table 1: Socio-demographic characteristics of the entire cohort and the deceased population**

	Entire cohort		Deceased population	
Variables	**Male**	**Female**	**Male**	**Female**
Number of cases	1193	1226	100	33
Age (years)				
18-30	156 (13.1)	169 (13.8)	2 (2)	0
31-40	242 (20.3)	326 (26.6)	3 (3)	3 (9.1)
41-50	318 (26.7)	343 (28.0)	19 (19)	8 (24.2)
51-60	267 (22.4)	244 (19.9)	25 (25)	11 (33.3)
>60	210 (17.6)	144 (11.8)	51 (51)	11 (33.3)
Level of education				
College	400 (33.5)	194 (15.8)	15 (15)	2 (6.1)
Attended school	487 (40.8)	411 (33.5)	43 (43)	9 (27.3)
No formal education	306 (25.7)	621 (50.7)	42 (42)	22 (66.7)
Occupation				
Not working	80 (6.7)	342 (27.9)	7 (7)	6 (18.2)
Sedentary workers	116 (9.7)	53 (4.3)	4 (4)	5 (15.2)
Manual workers/farmers	997 (83.6)	831 (67.8)	89 (89)	22 (66.7)
Socio-economic status				
Lower middle	515 (43.2)	856 (69.8)	64 (64)	26 (78.8)
Upper lower	677 (56.8)	370 (30.2)	36 (36)	36 (21.2)
Medical history (yes)				
Diabetes	186 (7.7)	131 (5.4)	28 (21.1)	2 (1.5)
Hypertension	408 (16.8)	312 (12.9)	60 (45.1)	22 (16.5)
Longstanding hypertension (≥5 yrs.)	95 (3.9)	66 (2.7)	22 (16.5)	6 (4.5)
Heart disease*	138 (5.7)	111 (4.6)	24 (18.1)	2 (1.5)
CKD	299 (12.4)	209 (8.7)	59 (44.4)	19 (14.3)
Place of death				
Home			77 (77)	29 (87.9)
Hospital			23 (23)	4 (12.1)

276 **self-reported conditions*

277

278 **Table 2: Leading cause-specific mortality fractions for all verbal autopsy deaths.**

	Gender		
Cause of Death	Males	Females	Total
Chronic Kidney Disease	43 (43)	17 (51.5)	60 (45.1)
Ischemic Heart Disease	14 (14)	6 (18.2)	20 (15)
Chronic Respiratory disorders	7 (7)	1 (3.0)	8 (6.0)
COVID-19	8 (8)	0	8 (6)
Stroke	4 (4)	3 (9.0)	7 (5.3)
Undetermined	4 (4)	4 (12.1)	7 (5.3)
Neoplasm	4 (4)	0	4 (3)
Diabetes	4 (4)	0	4 (3)
Transport accidents	4 (4)	0	4 (3)
Suicide	3 (3)	1 (9.0)	4 (3)
Cirrhosis	2 (2)	0	2 (1.5)
Other Infectious Diseases	1 (1)	1 (3.0)	2 (1.5)
Other Injuries	1 (1)	0	1 (0.8)
Other NCDs	0	1 (3.0)	1 (0.8)
TB	1 (1)	0	1 (0.8)
Total	100 (75.2)	33 (24.8)	133 (100)

279

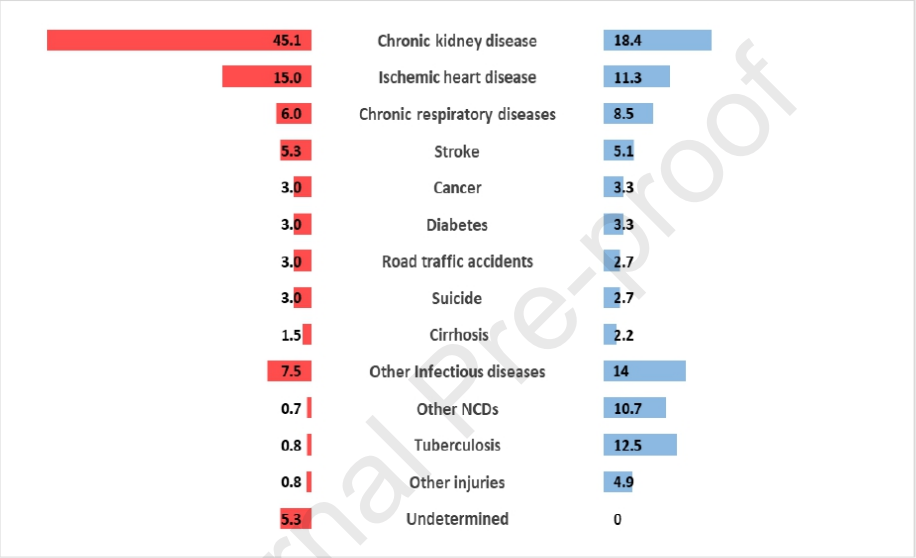
280 **Table 3: characteristics of the persons who died of CKD vs non-CKD among the cohort.**

Variables	**CKD Death (n=60)**	**Non-CKD Deaths (n=73)**
Gender		
Male	43 (71.7)	57 (78.1)
Female	17 (28.3)	16 (21.9)
Age (years)		
18-30	0 (0)	2 (2.7)
31-40	5 (8.3)	6 (6.8)
41-50	11 (18.3)	18 (24.6)
51-60	18 (30)	21 (28.7)
>60	26 (43.3)	37 (36.9)

Level of education		
College	3 (5)	14 (19.2)
Attended school	37 (61.7)	27 (37)
No formal education	20 (33.3)	32 (43.8)
Occupation		
Not working	52 (86.7)	59 (80.8)
Sedentary workers	5 (8.3)	8 (11)
Manual workers/farmers	3 (5)	6 (8.2)
Socio-economic status		
Lower middle	46 (76.7)	44 (60.3)
Upper lower	14 (23.3)	29 (39.7)
Medical history (yes)		
Diabetes	7 (5.3)	15 (11.3)
Hypertension	37 (61.7)	41 (56.7)
Longstanding hypertension (≥5 yrs)	11(18.3)	17 (23.3)
Heart disease*	12 (20)	14 (19.2)
CKD	35 (58.3)	11 (15.1)
Place of death		
Home	53 (88.3)	53 (72.6)
Hospital	7 (11.7)	20 (27.4)

281

Figure 1: Cause-specific mortality fractions for leading causes of death from verbal autopsy data in the STOP CKDu cohort, Uddanam region (n=133) compared with Global Burden of Disease estimates for India (age >20 years)



**Other infectious diseases include deaths due to COVID-19.*
**Other Non communicable diseases and Other injuries are as categorized from SmartVA tool.*
#Other NCDs deaths include deaths due to cardiovascular diseases (excluding Ischemic heart disease, Stroke), Musculoskeletal disorders, digestive disorders, neurological and mental health disorders, substance use disorders, and skin and subcutaneous diseases.
#Other injuries include deaths due to unintentional injuries and interpersonal violence.
#Other infectious diseases include deaths due to communicable diseases excluding Tuberculosis
#All calculations were done after excluding maternal deaths

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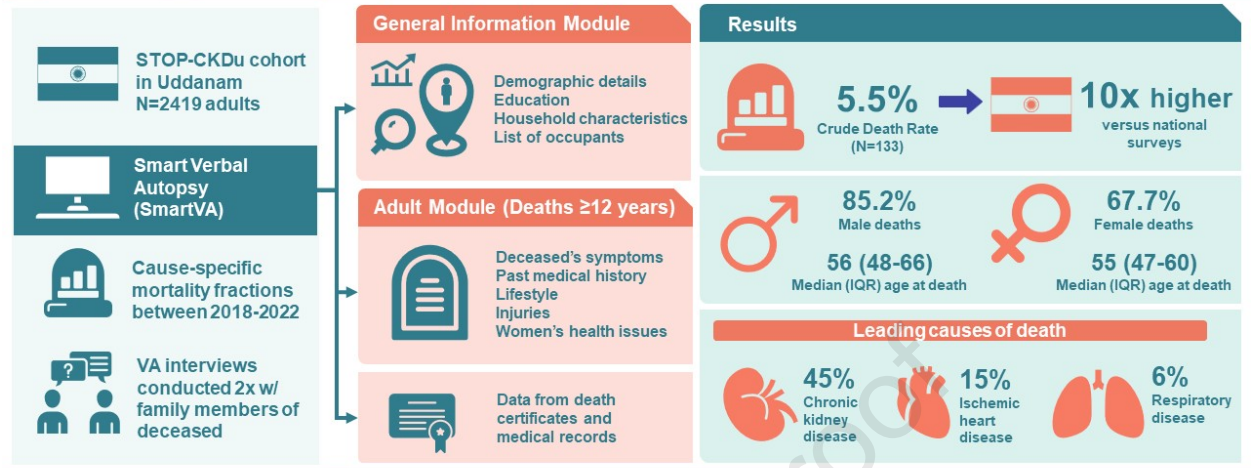

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Conclusion This study confirms CKD as the leading cause of mortality in this high CKD burden area and provides crucial data for public health decision-making and resource allocation.