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Causes and Distributions of Under-five Mortality in Alexandria Governorate Using the Verbal Autopsy and Social Autopsy Studies (VASA) Interviews

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Finally, we hope the result of this research can help in reducing the under-five mortality rates in Egypt.

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ABBREVIATIONS

CSMF	:	Cause specific mortality fraction
EDHS	:	Egypt Demographic Health Survey
EMRO	:	Eastern Mediterranean Regional
HD	:	Health District
HO	:	Health Office
ICD 10	:	International statistical classification of diseases
IMCI	:	Integrated management of childhood illness
LMIC	:	Low and middle income countries
MCH	:	Maternal and child health
MDG	:	Millennium developmental goal
MoHP	:	Ministry of Health and Population
NCD	:	Non-communicable diseases
U5MR	:	Under-five mortality rate
UN	:	United nations
VA	:	Verbal autopsy
VASA	:	Verbal autopsy and social autopsy studies
WHO	:	World Health Organization

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SUMMARY

Reduction of child mortality is one of the most strongly and universally supported developmental goals. Despite considerable progress in reducing child mortality, still there is a large gap between developed and developing countries in the risks of dying before age 5 years. New estimates in Levels and Trends in Child Mortality Report 2015 released by the United Nation Inter-Agency Group for Child Mortality Estimation indicated that although the global progress has been substantial, 16,000 children under five still die every day, and the 53 per cent drop in child mortality is not enough to meet the Millennium Development (MDG) Goal of a two-thirds reduction between 1990 and 2015.

Verbal autopsy (VA) is a method used to ascertain the cause of a death based on an interview with next of kin or other caregivers. This is done using a standardized questionnaire that elicits information on signs, symptoms, medical history and circumstances preceding death. VA is now widely used in low and middle income countries (LMIC) to estimate cause-specific mortality and is increasingly being used for disease surveillance and in sample registration systems. Software for interpreting VA indicators into causes of death without the use of physicians can be used in the majority of cases. This study aimed to determine the causes and distributions of under-five mortality (U5MR) in Alexandria Governorate using VA.

Alexandria is covered by 40 Health Offices (Hos) distributed over 8 Health Districts (HDs): Sharq, Gharb, Wasat, Gomrok, Amriya, Agamy, Montaza and Borg El-Arab The first phase, the record review phase, was conducted in 27 randomly selected health offices. The data of 3064 deceased under-five children were collected from the records of the selected 26 HOs. Out of the identified deaths, 19 cases were excluded as they were not residents in Alexandria, while 79 cases were excluded due to inaccessibility (wrong phone numbers and incomplete data). Among the remaining 2966 cases, they were initially contacted through their registered phone numbers. These phone calls aimed to introduce the participants to the study, and explain its objectives and benefits. 192 guardians refused to participate in the interview upon calling them, and 143 guardians initially accepted to participate but after planning for the interview they did not show up and ignored the calls. Out of the remaining 2631 cases, 929 cases

were inaccessible as they did not reply to the calls, 355 responded they did not register case deaths and 702 were not contacted. The final number who responded to the calls and were interviewed through VASA was 645.

Data collected from records:

- Records were reviewed in the 8 health districts of Alexandria from 27 Health Offices during the period from 01/01/2017 till 30/06/2019.
- The total number of recorded under-five deaths were 3064 cases.
- Neonatal mortality represented 58.3% of all U5MR. About 31.7% of children died after the age of 28 days and before the first birthday. Infant mortality was 90% of the U5MR.
- Childhood cardiovascular diseases were the most frequently reported causes of U5M, 20.60% followed by preterm delivery deliver 14.73%, pneumonia 11.83%, septic shock 9.71%, and congenital malformation 9.34%.
- The highest U5M was reported in Montaza District 29.06% (861/2966) (while the lowest mortality was reported in Gomorok 0.39%, (71/2966) and Borg El-ARab district 5.16% (153/2966).
- The overall U5M was higher in males than females, and within all age categories except (day 7-28 days).

Data analyzed by verbal autopsy:

- The response rate for VA was 66%.
- The majority of the interviewed guardians of deceased under-five children were of the neonatal group 70.07%. Early neonatal mortality (death within the first week of life) among both sexes was 61.2 %. The majority of U5M after the neonatal period was within the first birthday; 77.55% and 68.30% of males and females respectively.
- Smart VA:
  - ❖ The main causes of child death after the neonatal period were pneumonia (25.4%), childhood cardiovascular diseases (23%), digestive diseases (12%) and diarrheal dysentery (7.9%).
  - ❖ The main causes of neonatal mortality are preterm delivery, congenital malformation, neonatal pneumonia, and birth asphyxia (57.4%, 17.3%, 10.8%, and 8.3%).

- ❖ The causes of U5M is preterm delivery (40.2%), congenital malformation (12.25%), pneumonia (7.6%), and neonatal pneumonia (7.6%).
- ❖ The classification of cause of death by the global burden of diseases board categories revealed that, communicable diseases, maternal, neonatal and nutritional diseases causes 72% of U5M. Non communicable diseases represented 25.7% of all deaths and lastly injuries represented 2.4%.

- InsilicoVA analysis of the questionnaires revealed that; prematurity, birth asphyxia, acute respiratory infection including pneumonia, neonatal pneumonia are the main killer of the under-five children (32.9%, 23.3%, .8.7%, 5.1%).
- The results of interVA5 analysis revealed that birth asphyxia, neonatal pneumonia, congenital malformation, prematurity, and neonatal sepsis (19.8%, 15.1%, 14.9%, 12.1%, 10.9%) were the main killer of under-five children.

INTRODUCTION

Sustainable Development Goals (SDGs) are 17 goals that were set in 2015 by the United Nations (UN) with the aim of achieving better and sustainable future for all by the year 2030. Goal 3 of the SDGs is to "Ensure healthy lives and promote wellbeing for all at all ages". Target 3 of Goal 3 is "By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1000 live births and U5M to at least as low as 25 per 1000 live births".[1]

The under-five mortality rate (U5MR) is one of the indicators included in the Human Assets Index and is therefore one of the quantitative criteria for the identification of least developed countries within the UN.[2]

In 2018, 85% of deaths among children occurred in the first five years of life, accounting for 5.3 million deaths, of which about 47% (about 2.5 million) occurred in the first month of life (neonatal period) and about 29% (about 1.5 million) at age 1–11 months (infant period).[3]

The global U5MR has declined by more than half, dropping from 90 to 43 deaths per 1,000 live births between 1990 and 2015. Substantial progress in reducing child mortality has been made, but more children can be saved from death due to preventable causes. The fourth MDG, which was to reduce the U5MR by two-thirds between 1990 and 2015, was not achieved in most countries.[4] For many children, the socio-economic state and the geographic nature of their birth place determine their access to quality, affordable health care. Too many under-five children continue to die from easily preventable and treatable causes, because the world has failed to ensure their basic rights for survival and health. Current trends predict that around 52 million of under-five children will die between 2019 and 2030. While the global burden of child deaths remains high, children's chances of survival vary dramatically across regions and countries.[3]

As reported by the Egyptian Demographic Health Survey (EDHS, 2014) the infant mortality rate was 22 deaths per 1,000 births and the neonatal mortality rate was 14 deaths per 1,000 live births. A comparison of these rates with the overall level of

U5MR (27 deaths per 1,000 live births) indicates that almost 80% of early childhood deaths take place before a child's first birthday, with half occurring during the first month of life.[5] This figure was lower than what was reported in the EDHS in 2008, as both the under-five and neonatal mortality rates were 33.4 and 17.5 per 1,000 live births, respectively.[6] Both figures represented huge improvement in the maternal and child health (MCH) services since 1990, when the U5MR and neonatal mortality rates were 172 and 33 per 1,000 live births.[7]

In 2016, the Eastern Mediterranean Regional Office (EMRO) reported the most common causes of U5MR, which were prematurity (20.6%), followed by congenital anomalies, birth asphyxia and pneumonia (11.6%, 9.8% and 9.7%, respectively).[8]

Despite the efforts made to reduce the U5MR, critical data about the main causes of death are still lacking. Reliable data on the levels and causes of mortality are cornerstones for building a solid evidence base for health policy, planning, monitoring and evaluation. However, many national and local governments continue to rely on outdated data or data of insufficient quality for planning and decision making. Effective planning to diminish preventable child deaths requires information about the current distribution of causes of child deaths. Accurate and complete data with high quality regarding the causes of death and mortality, including the U5MR, should be available to support planning of public health interventions, resource allocation and evaluating the impact of such interventions.[9]

In 2019, Gewaifel et al reported that the quality of registration of causes of death at home in Alexandria health offices was poor.[10] Although complete vital registration systems with accurate medical certification of the causes of death are considered the best source for such all mortality data, particularly U5M data, yet these systems are challenging to be implemented, in terms of the needed human, non-human and financial resources, in large populations such as that of Egypt.[11]

Verbal autopsy (VA) inquiry of a child death consists of a retrospective interview on the signs and symptoms of the fatal illness with the mother or other caregiver of the child. [3] This is done using a standardized questionnaire that elicits information on signs, symptoms, medical history and circumstances preceding death. The cause of death, or the sequence of causes that led to death, are assigned based on

the data collected by a questionnaire and any other available information. VA is now widely used in LMIC to estimate cause-specific mortality, and is increasingly being used for disease surveillance and in sample registration systems.[12] In order to provide estimates of cause-specific U5M in Alexandria, Verbal Autopsy and Social Autopsy (VASA) interviews was conducted as a follow up to deaths identified by the 2014 EDHS.

AIM OF THE STUDY

This study aimed to determine the causes and distributions of under-five mortality in Alexandria Governorate using the verbal autopsy and social autopsy studies interviews.

Specific objectives:

1. To estimate the age specific and cause of under-five mortality.
2. To identify causes of under-five mortality in rural and urban areas.
3. To evaluate the role VA in identifying cause of death.

METHODS

Study design

A cross-sectional study design.

Study Setting

Alexandria is the second-largest city in Egypt and a major economic center. With a population count of 5,182,450. Alexandria is the sixth-largest city in the Arab world and the ninth-largest in Africa. The city extends about 32 km at the northern coast of Egypt along the Mediterranean Sea. Alexandria is covered by 40 Health Offices (Hos) distributed over 8 Health Districts (HDs): Sharq, Gharb, Wasat, Gomrok, Amriya, Agamy, Montaza and Borg El-Arab. The first phase, the record review phase, was conducted in 27 randomly selected health offices as shown in **Table (1).**[13]

Figure :I Map of Alexandria Governorate

Table 1: Distribution of the Health offices where health records were reviewed according to the health district (Alexandria, 2019)

	District	Number of Health Offices
1.	Sharq	4
2.	Gharb	4
3.	Wasat	4
4.	Gomrok	3
5.	Amriya	3
6.	Agamy	3
7.	Montaza	3
8.	Borg El-Arab	3
Total		27

Study population

Inclusion criteria:

- Deceased under-five children, confirmed by their reviewing their ages from the death record.
- Died during the last 30 months (between 01/01/2017 and 30/06/2019)
- Family is resident in Alexandria.
- Died at least 4 weeks from the start of the survey.

Exclusion criteria:

- No care-giver to respond to the questionnaire.
- If the family moved outside Alexandria and refused telephone based interview.

Data collection tools and procedures:

A. Record Review:

The data of 3064 deceased under-five children were collected from the records of the selected 27 HOs. Out of the identified deaths, 19 cases were excluded as they were not residents in Alexandria, while 79 cases were excluded due to inaccessibility

(wrong phone numbers and incomplete data). Among the remaining 2966 cases, they were initially contacted through their registered phone numbers. These phone calls aimed to introduce the participants to the study, and explain its objectives and benefits. 192 guardians refused to participate in the interview upon calling them, and 143 guardians initially accepted to participate but after planning for the interview they did not show up and ignored the calls. Out of the remaining 2631 cases, 929 cases were inaccessible as they did not reply to the calls, 355 responded they did not register case deaths and 702 were not contacted. The final number who responded to the calls and were interviewed was 645. The response rate for verbal autopsy was 645/ (143+192+645) = 66%. **Figure 1**

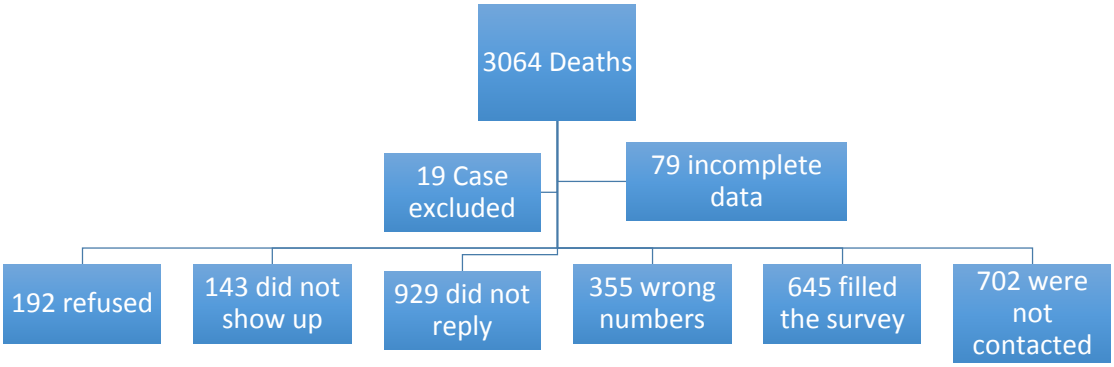

Figure 1: Diagram demonstrating the study procedures and respondents to the VA interviews (Alexandria, 2019)

B. Verbal Autopsy tool:

- **The 2016 WHO VA Instrument v1.5.1 tool was used.**
- **Validation of the Arabic version of the questionnaire:**

1. Translation of the English neonate and child versions of the questionnaire: Two groups of bilingual speakers translated the neonate and child versions of the questionnaire from English to Arabic, each group consisted of two junior staff and one senior researcher responsible for the

initial translation of one of the two WHO tools, the junior started the translation then revised by the senior. Then each team revised the translation of the other team (cross revision).

2. Back translation by a native speaker. One bilingual speaker, an English native speaker, translated the Arabic version back to English.
3. Validation of the Arabic version of the questionnaire.
A pilot sample of 30 patients was calculated to validate the questionnaires.

- **Development of data collection tool on ODK data collection program**
  1. Generating of the two questionnaires in the Excel format.
  2. Transforming the Excel file to xls format.
  3. Development of ODK Arabic form of the two questionnaires.
- **Two training workshops were carried out for the field team:**

  These workshops were held to familiarize the team members with tool, and to ensure their ability to use the application and to train them how to deal with the psychological issues that may arise during the interview and hinder data collection. It was translated into Arabic version and uploaded on the ODK data collection tool and the data collectors received intensive training upon it with a focus on how to deal with the guardians and any emotional upset that may have been elicited during the interview.
- **A pilot study was conducted prior to starting the actual field work to**:

  i. Estimate the average time needed to complete an interview with the guardian.
  ii. Identify if there were shortfalls in the translated version and test the language used.
  iii. Test the efficiency of the data collectors in using the tool.
  iv. Test the accuracy and completeness of the Excel files extracted from the ODK server.
  v. Identify any technical problems that may arise during the interview using the ODK.
  i. The feedback was the following:
  vi. The average time needed to complete an interview ranged from 20-30 minutes;

vii. Using more simple language rather than complex medical jargons to be easily understood by the target population especially those with very low educational level;

viii. No difficulties were encountered during the utilization of the ODK due to the mobile internet, and it was agreed to have a portable Wi-Fi device to facilitate this process.

ix. Skip logic functions of the ODK were tested and found out to be more time saving facilitated the interview process.

Data management and analysis

- **Data processing:** The data were extracted to (CSV) Excel worksheets from the ODK server to be fed into the analysis software.
- **Statistical analysis:**

Causes-of-death classification is based on the *International statistical classification of diseases and related health problems*, tenth revision (ICD 10) which is the mandatory level of coding for international reporting to the WHO mortality database, has 21 chapters and 2046 categories of diseases, syndromes, external causes or consequences of the external causes.[14]

Analysis processes compatible with the WHO 2016 VA instrument

Three automated diagnostic algorithms that are freely available, have been evaluated for acceptable performance, are compatible for use with the WHO 2016 VA instrument, and can be used in routine civil registration vital statistics systems (CRVS).

The InterVA algorithm

Based on Bayes' rule for conditional probabilities, for a single death InterVA produces values for the propensity of each cause given the indicators reported as present in a VA interview and a set of evidence-based and physician-derived conditional probabilities describing the typical likelihood of each indicator for deaths of each cause. For a set of deaths, InterVA sums across the largest propensities for each cause to yield the population-level fraction of deaths resulting from each cause. For each death, InterVA reports single value point estimates for the propensity of the 3 causes with the largest propensities, if they fall above a set threshold; otherwise, the cause is ruled "indeterminate."[15]

InSilicoVA

It is a statistical algorithm that, for a set of deaths, identifies the most likely joint probability distribution of cause-specific mortality fractions and probabilities of each cause for each individual death. This is done using a Bayesian hierarchical model fit using a Gibbs sampling algorithm that uses information on both the presence and absence of VA indicators and the conditional probability of each VA indicator for deaths of each cause. InSilicoVA reports probability distributions and summaries of those distributions for each cause-specific mortality fraction and the probability of each cause for each death. This is a first step in accounting for the inherent uncertainty in assigning causes to deaths using VA.[16]

SmartVA and Tariff 2.0

Tariff method, is an approach that balances data-driven machine-learning methods with a level of interpretability necessary for methodological acceptance (this balance is coming to be known as "explainable artificial intelligence"). The Tariff method produces a set of tariff scores for each disease–symptom pair, which can be interpreted as a robust analogue to a z-score and indicate the relatedness of each symptom to each cause.[17]

Ethical considerations

- The approvals of the Ethics Committee of the High Institute of Public Health.
- and the Central Directorate for Research and Health Development were sought for conducting the research.
- The research team complied with the International Guidelines for Research Ethics. A written informed consent was taken from all the guardians of the study participants after explanation of the purpose.
- Confidentiality and anonymity were assured.

RESULTS

Overall deaths among the recorded cases

About 38% of all deaths occurred within the first week of life, while 20.1% deaths took-place between the ages of 7-28 days of life. Neonatal mortality represented 64.8%, and 58.3% of infant mortality, and U5M. About 31% of children died after the age of 28 days and before the first birthday. Infant mortality represented 90% of the U5M. **Figure 2**

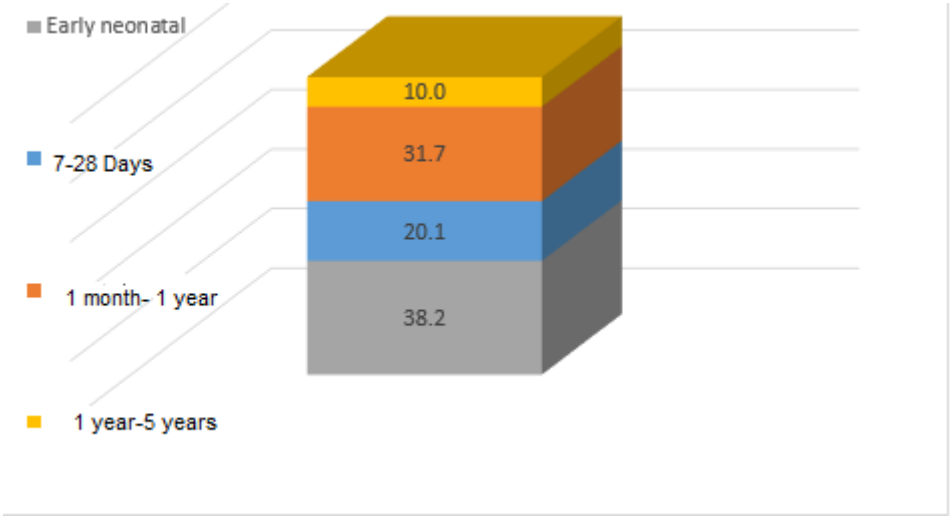

Figure 2: Distribution of the age-specific deaths among the studied children (Alexandria, 2019)

Causes of death based on death certificate

Among the studied causes of deaths; childhood cardiovascular diseases were the most frequently reported cause 20.60% (611/2966) followed by preterm delivery deliver 14.73% (437/2966), pneumonia 351/2966 (11.83%), septic shock 9.71% (288/2966), congenital malformation, 9.34% (277/2966). **(Figure 3, Table 2)**

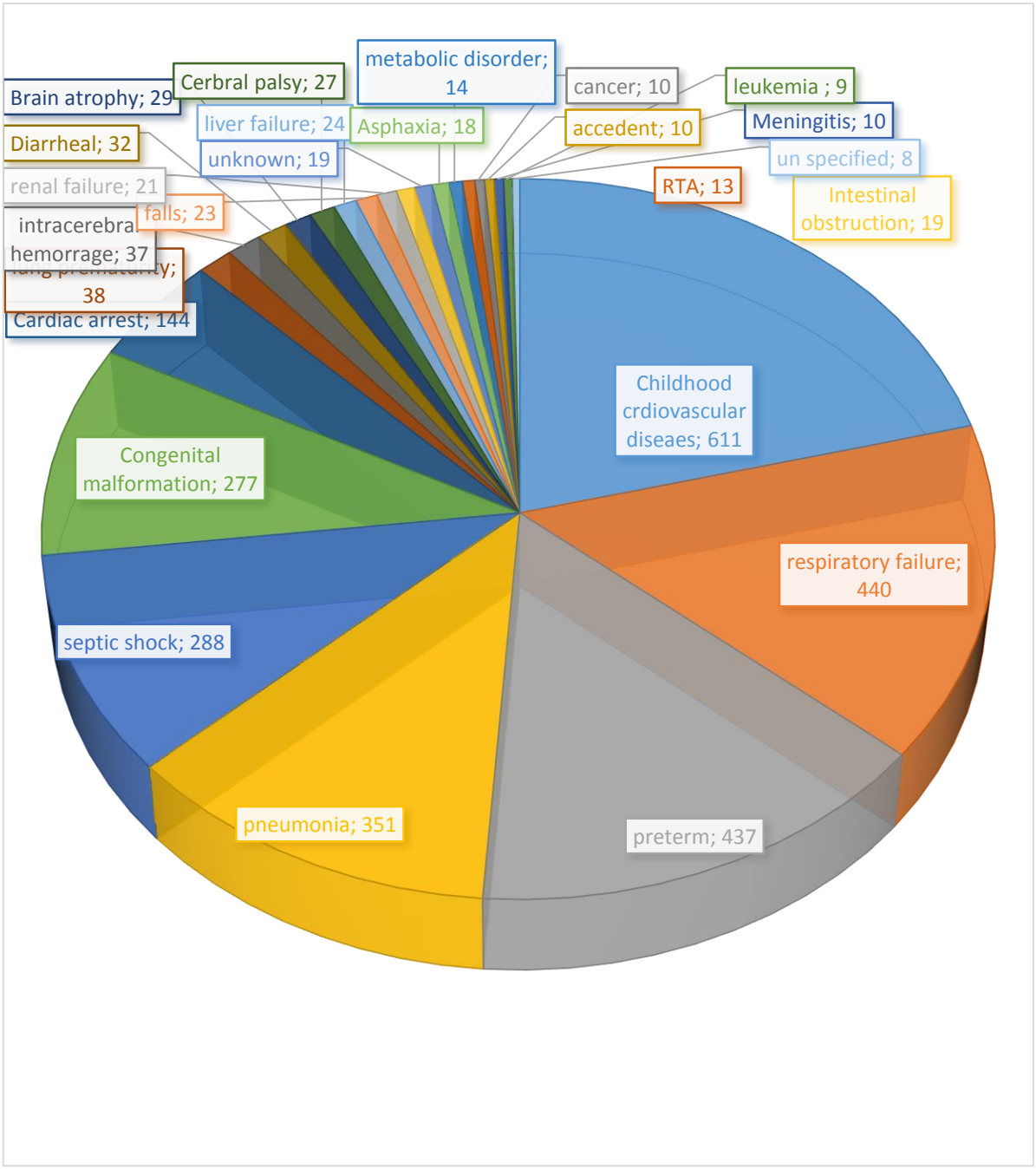

Figure 3: Distribution of the causes of Under-five mortality based on death certificate (Alexandria, 2019)

Table 2: Distribution of the causes of under-five mortality based on death certificate (Alexandria, 2019)

Cause of death	Number	Percentage
Childhood cardiovascular diseases	611	20.60
Respiratory failure	440	14.83
Preterm	437	14.73
Pneumonia	351	11.83
Septic shock	288	9.71
Congenital malformation	277	9.34
Cardiac arrest	144	4.86
Lung prematurity	38	1.28
Intracerebral hemorrhage	37	1.25
Diarrheal	32	1.08
Brain atrophy	29	0.98
Cerebral palsy	27	0.91
Liver failure	24	0.81
Falls	23	0.78
Renal failure	21	0.71
Intestinal obstruction	19	0.64
Unknown	19	0.64
Asphyxia	18	0.61
Metabolic disorder	14	0.47
Road traffic accident	13	0.44
Cancer	10	0.34
Accident	10	0.34
Meningitis	10	0.34
Leukemia	9	0.30
Un specified	8	0.27
Drowning	7	0.24
Hiatal hernia	7	0.24
Brain defect	6	0.20
Lung prematurity	6	0.20
Convulsion	6	0.20
Fire	4	0.13
Internal hemorrhage	3	0.10
Stroke	2	0.07
Electric shock	2	0.07
Respiratory distress syndrome	2	0.07
Fracture	2	0.07
Suffocation	2	0.07
Other causes*	8	024

* Other causes: Cerebral edema, ascites, nervous system disease, esophageal varices, pulmonary hemorrhage, malnutrition, peritonitis, and pulmonary embolism; each was reported once only.

Table 3 shows the distribution of U5M within each district at different ages; the highest mortality rate was in Montaza district while the lowest mortality was in Gomrok and Borg El-Arab district. The majority of deaths occurred within the neonatal period. 38.2% (1134/2966)

Table 3: Distribution of under-five mortality according to age and sex within each district (Alexandria, 2019)

District	**Gomrok**						**Total**
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	3	7	13	10	7	1	41
Female	2	6	6	9	7	0	30
total	5	13	19	19	14	1	71
District	**Amriya**						**Total**
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	13	23	74	35	95	37	277
Female	8	21	44	67	73	15	228
total	21	44	118	102	168	52	505
District	**Agamy**						**Total**
Ag	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	11	18	34	44	73	28	208
Female	14	11	36	45	77	26	209
total	25	29	70	89	150	54	417
District	**Montaza**						**Total**
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	47	45	130	82	130	49	483
Female	26	30	88	82	108	44	378
total	73	75	218	164	238	93	861
District	**Borg**						**Total**
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	5	3	11	18	41	8	86
Female	2	5	5	9	37	9	67
total	7	8	16	27	78	17	153
District	**Sharq**						**Total**
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	14	17	13	38	45	16	143
Female	11	14	25	30	52	13	145
total	25	31	38	68	97	29	288

District	Waset						Total
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	12	21	59	31	43	20	186
Female	12	15	44	34	41	13	159
total	24	36	103	65	84	33	345
District	**Gharb**						**Total**
Age	Before the end of the first 24 h	after the 24 h	D2-D7	<28 days	1 year	under-five	
Male	16	10	60	30	60	11	187
Female	10	11	29	31	51	7	139
total	26	21	89	61	111	18	326
Total	**206**	**257**	**671**	**595**	**940**	**297**	**2966**

Figure 4 shows that deaths of males were higher than females, deaths within the first 48 hours represented 16% and 14% (265/1611 and 198/1355) among males and females respectively.

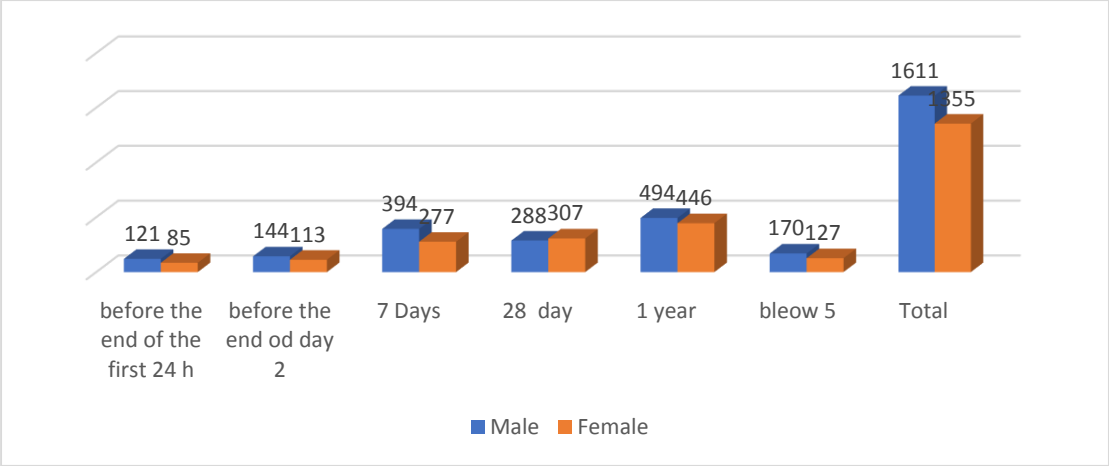

Figure 4: Distribution of under-five mortality according to age and sex within each district (Alexandria, 2019)

Description of overall study sample who completed the verbal autopsy

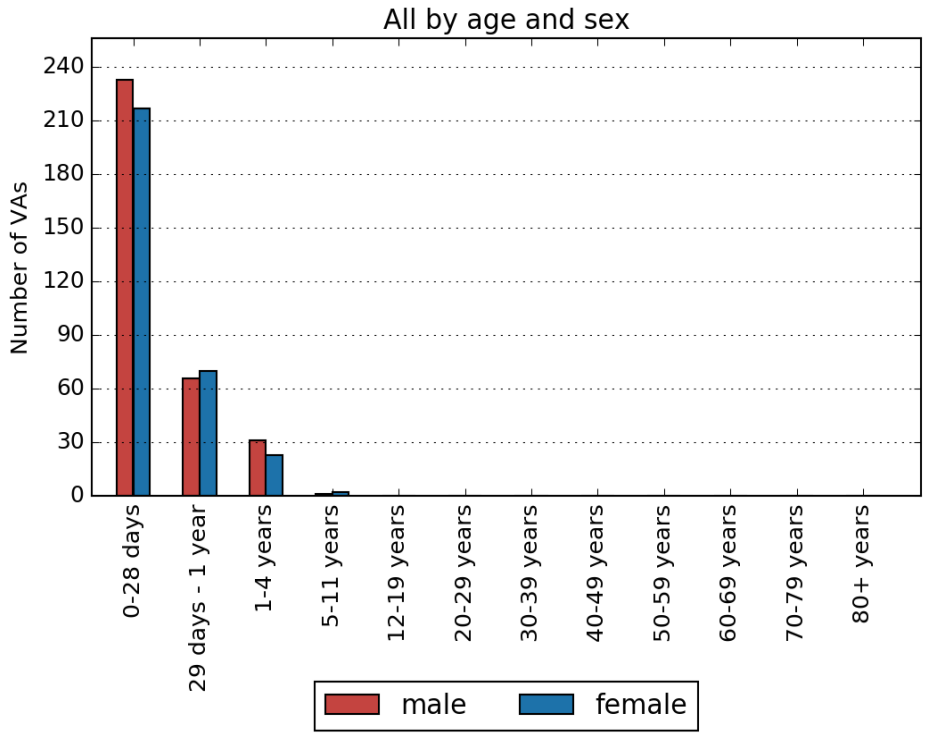

Figure 5: Distribution of the cases who completed the VA according to age and sex of the deceased children (Alexandria, 2019)

This table shows that the majority of the interviewed U5M was of the neonatal group (452/645). Early neonatal mortality among both sexes was 61.2 %. The majority of U5M after the neonatal period is within the first birthday; 77.55 and 68.30 of males and females respectively.

Table 4: Distribution of the cases who completed the VA according to age and sex of the deceased children (Alexandria, 2019)

Age	< 28 day			>28 day			total
	total	< 7 days	7-28 days	total	28d- 1 y	1-5 years	
Male	233	143(61.37)	90(38.63)	98	76 (77.55)	22(22.45)	**331**
Females	219	134(61.20)	85 (38.80)	95	82(68.30)	13 (31.20)	**314**
Total	**452(70.0)**	**277**	**175**	**193(30.0)**	**158**	**35**	**645**

Analysis of the under-five mortality using SmartVA

Child mortality:

The main causes of child death (1- 5 years) are pneumonia (25.4%), childhood cardiovascular diseases (23%), digestive diseases (12%) and diarrheal dysentery (7.9%). (**Table 5, figure 6**)

Table 5: Distribution of causes of under-five mortality using Smart VA (Alexandria, 2019)

Cause	ICD 10	Overall	Male	Female
Fires	X09	0.001	0.001	0.001
Encephalitis	G04	0.007	0.008	0.006
Hemorrhagic fever	A99	0.01	0.005	0.014
Poisonings	X49	0.01	0.012	0.008
Sepsis	A41	0.015	0.017	0.013
Drowning	W74	0.018	0.023	0.012
Road Traffic	V89	0.019	0.024	0.013
Measles	B05	0.025	0.014	0.035
Other Infectious Diseases	B99	0.028	0.034	0.02
Falls	W19	0.03	0.045	0.014
Childhood Cancer	C76	0.035	0.046	0.022
Meningitis	G03	0.05	0.076	0.021
Other Defined Causes of Child Deaths	UU2	0.068	0.095	0.036
Diarrhea/Dysentery	A09	0.079	0.089	0.064
Digestive Diseases	K92	0.12	0.115	0.118
Childhood Cardiovascular Diseases	I99	0.23	0.219	0.228
Pneumonia	J22	0.254	0.145	0.351

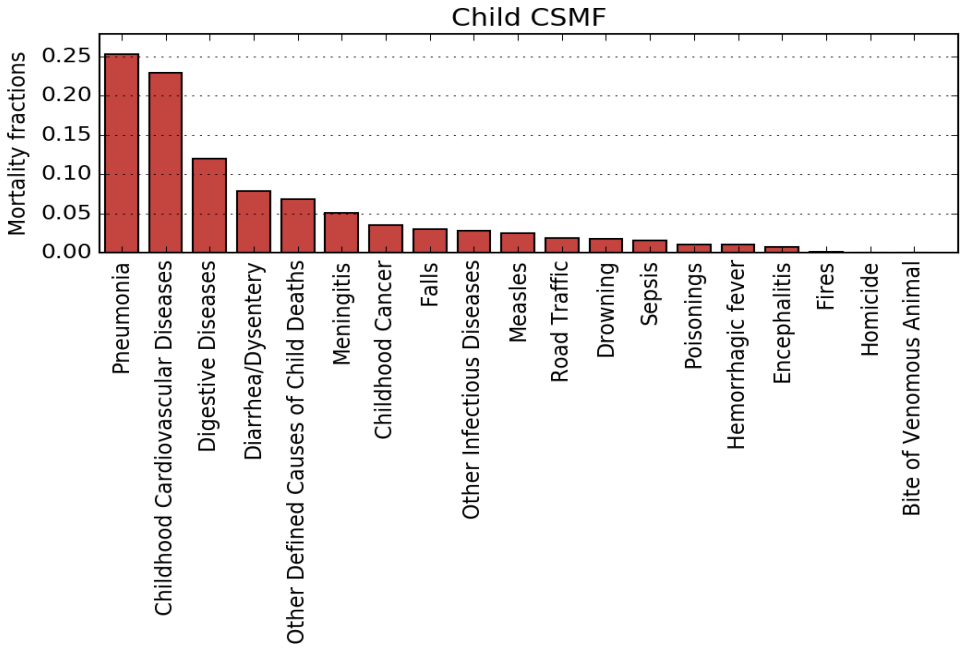

Figure 6: Distribution of causes of under-five mortality using Smart VA (Alexandria, 2019)

Neonatal mortality

Table 6, Figure 7 show that the main causes of neonatal mortality were preterm delivery, congenital malformation, neonatal pneumonia, and birth asphyxia in both sexes (57.4%, 17.3%, 10.8%, and 8.3%)**.**

Table 6: Distribution of causes of neonatal mortality using Smart VA (Alexandria, 2019)

Cause	ICD 10	All	Male	Female
Neonatal Meningitis/Sepsis	P36	0.03	0.033	0.027
Stillbirth	P95	0.031	0.031	0.032
Birth asphyxia	P21	0.083	0.063	0.104
Neonatal Pneumonia	P23	0.108	0.124	0.093
Congenital malformation	Q89	0.173	0.153	0.188
Preterm Delivery	P07	0.574	0.596	0.556

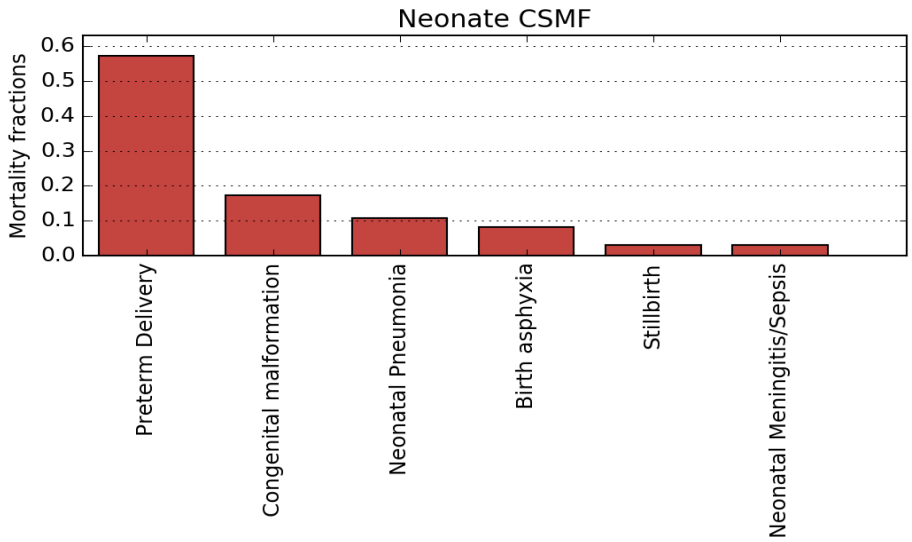

Figure 7: Distribution of causes of neonatal mortality using Smart VA (Alexandria, 2019)

Under-five mortality

The over-all causes of U5M is shown in **Table 7**; preterm delivery (40.2%), congenital malformation (12.2%), pneumonia (7.6%), and neonatal pneumonia (7.6%) are the main killer of children in Alexandria based on smart VA analysis. These four causes incriminated in 68% of all deaths.

Table 7: Distribution of the over-all causes of under-five mortality using Smart-VA (Alexandria, 2019)

Cause	ICD 10	All	Male	Female
Encephalitis	G04	0.002	0.002	0.002
Hemorrhagic fever	A99	0.003	0.002	0.004
Poisonings	X49	0.003	0.003	0.003
Drowning	W74	0.005	0.007	0.004
Sepsis	A41	0.005	0.005	0.004
Road Traffic	V89	0.006	0.007	0.004
Measles	B05	0.008	0.004	0.01
Other Infectious Diseases	B99	0.008	0.01	0.006
Falls	W19	0.009	0.013	0.004
Childhood Cancer	C76	0.01	0.014	0.006
Meningitis	G03	0.015	0.023	0.006
Other Defined Causes of Child Deaths	UU2	0.02	0.028	0.011
Neonatal Meningitis/Sepsis	P36	0.021	0.023	0.019
Stillbirth	P95	0.022	0.022	0.022
Diarrhea/Dysentery	A09	0.024	0.027	0.019
Digestive Diseases	K92	0.036	0.034	0.035
Birth asphyxia	P21	0.058	0.044	0.073
Childhood Cardiovascular Diseases	I99	0.069	0.065	0.068
Neonatal Pneumonia	P23	0.076	0.087	0.065
Pneumonia	J22	0.076	0.043	0.105
Congenital malformation	Q89	0.122	0.107	0.132
Preterm Delivery	P07	0.402	0.418	0.39

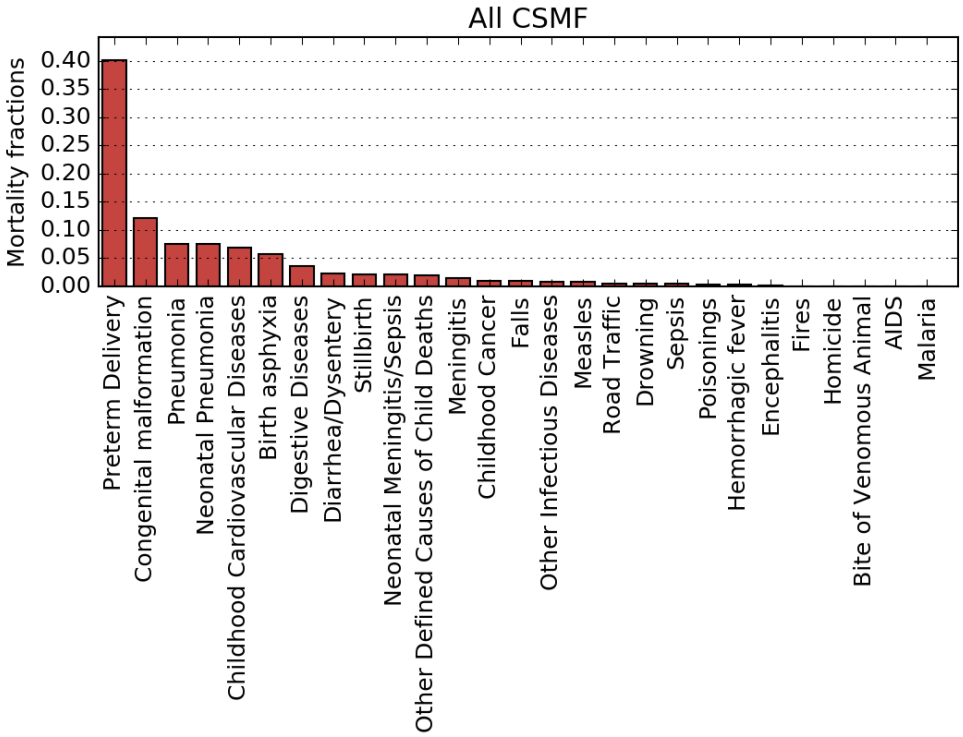

Figure 8 :Distribution of the over-all causes of under-five mortality using Smart-VA (Alexandria, 2019)

Table 8 shows that the classification of cause of death by the global burden of diseases board categories revealed that, communicable diseases, maternal, neonatal and nutritional diseases causes 72% of under-five deaths. Non communicable diseases represented 25.7% of all deaths and lastly injuries represented 2.4% (**figure 9**).

Table 8: CSMF by the global burden of disease broad categories (Alexandria, 2019)

Cause	CSMF
Communicable, maternal, neonatal and nutritional diseases	0.719
Non-communicable diseases	0.257
Injuries	0.024

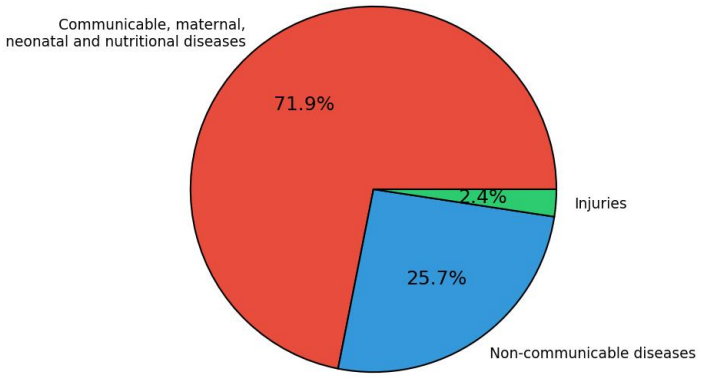

Figure 9: CSMF by the global burden of disease broad categories (Alexandria, 2019)

The undetermined cause of death is illustrated in **Figure 10**, the total number of unidentified cause of death using SmartVA was 148 cases; higher number was in males than in females. Higher percentage of undetermined causes was in earlier than in older age group.

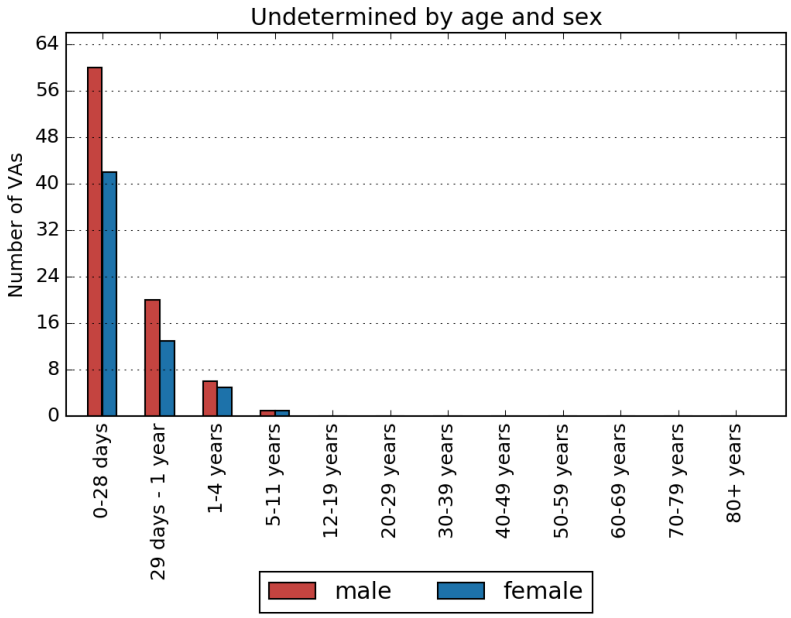

Figure 10: Undetermined cases by age and sex using smartVA (Alexandria, 2019)

Analysis of the under-five mortality using InsilicoVA

SmartVA analysis of the questionnaires revealed that; prematurity, birth asphyxia, acute respiratory infection including pneumonia, neonatal pneumonia, and neonatal sepsis are the main were the main accused condition associated with U5M (32.9%, 23.3%, .8.7%, 5.1%, and 3.5%) respectively. (**Table 9, Figure 11**)

Table 9: Causes of under-five mortality using InsilicoVA (Alexandria, 2019)

Cause	Mean	Std Error	Lower	Median	Upper
Prematurity	0.3287	0.0194	0.2888	0.3280	0.3672
Birth asphyxia	0.2328	0.0186	0.1982	0.2324	0.2733
Acute resp infect incl pneumonia	0.0865	0.0115	0.0634	0.0869	0.1093
Neonatal pneumonia	0.0510	0.0099	0.0324	0.0513	0.0708
Neonatal sepsis	0.0353	0.0074	0.0221	0.0346	0.0510
Diarrheal diseases	0.0343	0.0075	0.0211	0.0340	0.0497
Congenital malformation	0.0316	0.0073	0.0185	0.0311	0.0470
Other and unspecified infect dis	0.0310	0.0073	0.0186	0.0305	0.0477
Severe malnutrition	0.0307	0.0073	0.0173	0.0302	0.0451
HIV/AIDS related death	0.0180	0.0059	0.0073	0.0178	0.0301
Fresh stillbirth	0.0152	0.0063	0.0056	0.0144	0.0302
Sickle cell with crisis	0.0148	0.0069	0.0046	0.0139	0.0290
Liver cirrhosis	0.0083	0.0040	0.0026	0.0079	0.0179
Renal failure	0.0081	0.0038	0.0029	0.0074	0.0177
Accid fall	0.0074	0.0000	0.0074	0.0074	0.0074
Epilepsy	0.0073	0.0030	0.0014	0.0070	0.0137
Other and unspecified cardiac dis	0.0068	0.0032	0.0018	0.0068	0.0136
Road traffic accident	0.0050	0.0000	0.0050	0.0050	0.0050
Acute abdomen	0.0045	0.0030	0.0006	0.0039	0.0119
Accid drowning and submersion	0.0041	0.0000	0.0041	0.0041	0.0041
Other transport accident	0.0032	0.0000	0.0032	0.0032	0.0032
Macerated stillbirth	0.0028	0.0026	0.0002	0.0018	0.0087
Dengue fever	0.0027	0.0017	0.0007	0.0024	0.0073
Meningitis and encephalitis	0.0024	0.0021	0.0003	0.0018	0.0073
Exposure to force of nature	0.0024	0.0000	0.0024	0.0024	0.0024
Pertussis	0.0023	0.0021	0.0003	0.0016	0.0082
Stroke	0.0020	0.0022	0.0004	0.0013	0.0091
Ectopic pregnancy	0.0015	0.0013	0.0001	0.0009	0.0046
Anaemia of pregnancy	0.0014	0.0011	0.0002	0.0009	0.0039
Asthma	0.0014	0.0011	0.0001	0.0010	0.0044
Haemorrhagic fever (non-dengue)	0.0013	0.0013	0.0002	0.0008	0.0048
Other and unspecified neonatal	0.0013	0.0010	0.0002	0.0010	0.0044
Severe anaemia	0.0012	0.0010	0.0002	0.0009	0.0042
Intentional self-harm	0.0012	0.0000	0.0012	0.0012	0.0012

Other and unspecified external	0.0011	0.0000	0.0011	0.0011	0.0011
Malaria	0.0010	0.0008	0.0002	0.0008	0.0035
Pulmonary tuberculosis	0.0010	0.0011	0.0000	0.0006	0.0038
Abortion-related death	0.0009	0.0007	0.0001	0.0007	0.0025
Measles	0.0009	0.0008	0.0001	0.0006	0.0025
Other and unspecified neoplasms	0.0008	0.0005	0.0002	0.0007	0.0021
Diabetes mellitus	0.0008	0.0005	0.0002	0.0006	0.0024
Tetanus	0.0007	0.0007	0.0002	0.0005	0.0028
Pregnancy-related sepsis	0.0007	0.0004	0.0002	0.0006	0.0018
Obstructed labor	0.0007	0.0005	0.0001	0.0005	0.0020
Obstetric hemorrhage	0.0004	0.0005	0.0000	0.0002	0.0020
Sepsis (non-obstetric)	0.0004	0.0001	0.0002	0.0004	0.0006
Acute cardiac disease	0.0004	0.0004	0.0001	0.0002	0.0017
Pregnancy-induced hypertension	0.0003	0.0003	0.0000	0.0003	0.0010
Assault	0.0003	0.0000	0.0003	0.0003	0.0003
Chronic obstructive pulmonary dis	0.0003	0.0003	0.0001	0.0002	0.0011
Other and unspecified NCD	0.0002	0.0001	0.0000	0.0002	0.0005
Other and unspecified maternal CoD	0.0002	0.0001	0.0000	0.0001	0.0005

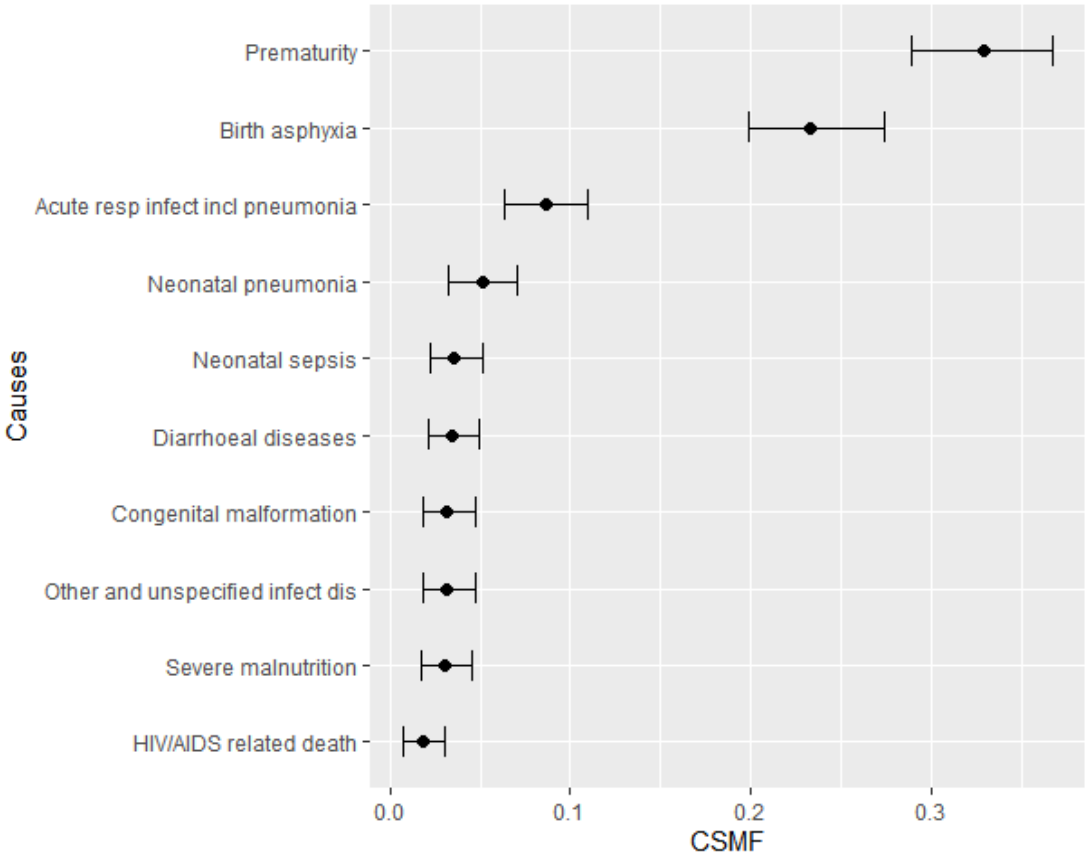

Figure 11: Causes of under-five mortality using InsilicoVA (Alexandria, 2019)

Analysis of the under-five mortality using InterVA5

Table 10, Figure 12 shows the results of interVA5 analysis, birth asphyxia, neonatal pneumonia, congenital malformation, prematurity, and neonatal sepsis (19.8%, 15.1%, 14.9%, 12.1%, 10.9%) were the main killer of under-five children.

Table 10: Causes of under-five mortality using InterVA5 (Alexandria, 2019)

cause	likelihood
Birth asphyxia	0.1983
Neonatal pneumonia	0.1509
Congenital malformation	0.1489
Prematurity	0.1214
Neonatal sepsis	0.1086
Diarrhoeal diseases	0.0371
Other and unspecified infect dis	0.0329
Undetermined	0.0314
Meningitis and encephalitis	0.0248
Other and unspecified cardiac dis	0.0201
HIV/AIDS related death	0.0181
Acute resp infect incl pneumonia	0.0142
Epilepsy	0.0112
Accid fall	0.0101
Severe malnutrition	0.0101
Tetanus	0.0095
Renal failure	0.0092
Road traffic accident	0.0062
Liver cirrhosis	0.0060
Accid drowning and submersion	0.0041
Other and unspecified neoplasms	0.0040
Other transport accident	0.0039
Fresh stillbirth	0.0038
Exposure to force of nature	0.0029
Sepsis (non-obstetric)	0.0028
Diabetes mellitus	0.0023
Macerated stillbirth	0.0021
Acute cardiac disease	0.0021
Malaria	0.0017
Other and unspecified external CoD	0.0013

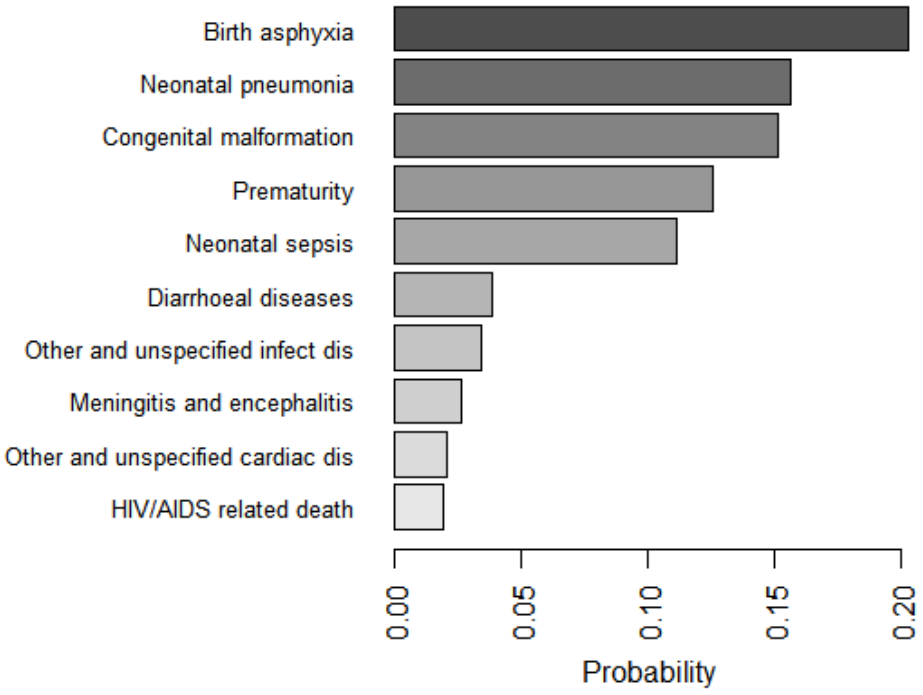

Figure 12: Causes of under-five mortality using InterVA5 (Alexandria, 2019)

DISCUSSION

Child mortality under the age of 5 is a critical issue for demographers and specialists in public health and a key predictor of the wellbeing of communities, cultures and the world as a whole. This represents a country's macroeconomic and public health priorities and values at the policy-making stage. The World Health Organization (WHO) reported an average annual decline rate for U5M from about 2% per annum from 1990–2000 to about 4% from 2000–2015. The change, however, was not sufficient to meet MDG4.[18]

Civil registration and vital statistics is an essential administrative system in modern society. The civil registry provides individuals with essential legal documents required to secure their identity, nationality and civil rights and access social services. Well-functioning civil registration and vital statistics systems are crucial for creating inclusive societies, ensuring proper delivery of public services and realizing and protecting basic human rights of all individuals.[19] Critical information on population health is needed to inform planning, resource allocation program implementation, monitoring, and evaluation. Since many countries lack complete vital registration systems, one of the key pieces of information about population health is missing causes of death. Understanding what the most prevalent causes of death are in a given population can help target preventive interventions and provide health services. Verbal autopsy (VA) is a method of determining individuals' causes of death and cause-specific mortality fractions in populations without a complete vital registration system.[20]

Globally, U5MR has decreased by 59%, from an estimated rate of 93 deaths per 1000 live births in 1990 to 39 deaths per 1000 live births in 2018. This is equivalent to 1 in 11 children dying before reaching age 5 in 1990, compared to 1 in 26 in 2018.In 2018, the U5M rate in LMIC was 68 deaths per 1000 live births – almost 14 times the average rate in high-income countries (5 deaths per 1000 live births). Reducing these inequities across countries and saving more children's lives by ending preventable child deaths are important priorities.[21]

Current situation of U5M in Egypt

Over the last 50 years, child mortality rate of Egypt was declining at a moderating rate to shrink from 247.3 deaths per 1,000 live births in 1969 to 21.2 deaths per 1,000 live births in 2018. Neonatal mortality rate of Egypt was declining at a

moderating rate to shrink from 59.2 deaths per 1,000 live births in 1969 to 11.2 deaths per 1,000 live births in 2018 and infant mortality rate of Egypt was declining at a moderating rate to shrink from 164.9 deaths per 1,000 live births in 1969 to 18.1 deaths per 1,000 live births in 2018.[22]

Death records review

Data for under five mortality

Eight teams were collecting data from records of the eight health administrative units in Alexandria. The teams collected 3064 deaths; 19 cases were excluded as they were living outside Alexandria and another 79 deaths were having incomplete data and excluded. About 2966 cases were studied for the underlying cause of death (COD).

In current research, based on review of death records; 38.2% of U5M was within the first week of life, neonatal mortality represented 64.8% and 58.3% of infant mortality, and U5M. Infant mortality represented 90% of U5M. One-tenth died after the first birthday and before the fifth. On the other hand, of the U5M, lower neonatal deaths (54%, and 52%) were reported by the WHO and UNICEF; Moreover, 63.1 of infant mortality was within the neonatal period. [23]

In the current research, childhood cardiovascular disease was the most frequent reported cause (611/2966, 20.60%), followed by respiratory failure (440/2966, 14.83%), preterm delivery (473/2966,14.73%), pneumonia (351/2966, 11.83%), septic shock (288/2966, 9.7%) and congenital anomaly (277/2966, 9.33%). These figures were slightly different from the most commonly reported causes of under-five mortality in Egypt which were distributed as follows; prematurity 20.7%, pneumonia (neonatal pneumonia or pneumonia)12.8%, congenital anomalies 11.6%, birth asphyxia 9.8%, other causes comprised 25.7%. Neonatal deaths represent 52% of U5M.[8]

The highest U5M was reported in El-Montaza district; 27.5% this may be due to wide geographic representation of this district, high population density, and difference in social class levels. On the other hand, the lowest U5M was reported in El-Gomrok district due to few number of health offices within this district. Another notable issue is that, (206+257) 15.58% of U5M occurred within the first 48 hours of life. Moreover; male mortality is higher than females in all age categories except in the age category of (7-28 days).

- Based on the results obtained from records; many issues important needs to be to declared:

First: 144 cases were attributed to cardiac arrest, which was not supposed to be the underlying COD as recommended.

Second: It was found that the focus was on reporting the underlying causes of death in the death certificates rather than the direct COD. i.e; cerebral palsy, ascites, fractures, etc.

For instance, spontaneous bacterial peritonitis (SPB) is (the direct cause) of hepatitis B (the underlying cause), and ascites is (antecedent cause).

Hepatitis B (underlying cause) ⟶ ascites (antecedent cause) ⟶ SBP (direct cause)

This highlights the urgent need for extensive training to be directed to early career physicians who receive their first job at the local health care units and they become responsible for issuing the death certificate. However, they are neither trained well during their academic years on how to issue a death certificate, nor at their early career.

Third: all unspecified causes (8 cases) that cannot explain the real COD by itself was collected like fever. Fever as a COD needs further clarifications.

Fourth: Training of health care workers on using ICD 10 should be provided to improve death registration as it is not used in death registers at the level of Health Office. It was reported that ICD 10 is used only for vital statistics electronic database at the central level.

Fifth: Contact information (address and telephone numbers) of death cases should be provided correctly. Some cases were registered using the telephone number of the health care worker.

Data for verbal autopsy mortality

Of 2966 deaths, 645 cases filled the interview.

Analysis of results:

There are several approaches to derive COD from VA: physician review, predefined expert algorithms, and data driven algorithms. The cause-specific mortality

fraction should be primarily based on the underlying COD as defined in ICD-10. (4) In this research, data was analyzed using three available soft wares; the smart VA, InterVA5, and InsilicoVA.

Response rate:

The response rate to verbal autopsy in this study was 66% of those who has been contacted; non responders include those who either refuse to make the interview or those did not attend the interview after their initial acceptance. A response rate of 96% was reported in another study conducted in Mexico. [24] Moreover, a higher response rate was achieved; about 99.5% response rate, however, actually only 66 deaths were included in this survey.[25] This lower response rate in Egypt is due to lack of the knowledge and awareness about verbal autopsy, even among the health care workers themselves.

VA analysis

In this study, the majority of the under-five mortality whose guardian had VASA were of the neonatal age group 452/645 (70.1%). Moreover, the majority of neonatal mortality is within the first week of life 277/452 (61.3%). Overall, 452/610 (74.1%) of infant mortality occurred within the neonatal period. Regarding child mortality, 81% of child mortality was within the first year of life.

1. **Smart VA analysis**

Based on smart VA analysis; the main causes of U5M in this research were birth asphyxia 5.8%, childhood cardiovascular diseases 6.9%, congenital malformation 15.2%, pneumonia whether (neonatal pneumonia or pneumonia) 15.2% preterm delivery 40.2%. The main causes of child deaths are, diarrheal diseases and dysentery 8.9%, digestive diseases 12%, childhood cardiovascular diseases 23%, and pneumonia 25.4%. The main causes of neonatal mortality are neonatal sepsis/meningitis 3%, stillbirth 3.1%, birth asphyxia 8.3%, neonatal pneumonia 10.8, congenital malformation 17.3% and preterm delivery 57.4%.

Communicable diseases were on top of the list of the causes of U5M, represented 71.9% followed by NCDs (25.7%), and injuries (2.4%). On the same line, communicable diseases, such as diarrheal diseases and acute respiratory infections,

along with malaria, constitute the main killers for the under-5 years' age group in developing countries located in Africa and Mediterranean region.[26, 27] This is mainly due to poor access to health services, low vaccination coverage and poor housing conditions.

The total number of individual COD diagnosed as undetermined is 148 cases. Smart VA carry two types of analysis; individual cause and CSMF. Unlike in the individual cause report of Smart VA analysis, for CSMF there are no 'Undetermined' causes of death. This is because SmartVA-Analyze redistributes the VAs with undetermined COD using a combination of two methods. Firstly, a VA with undetermined COD is fractionally distributed amongst all VA causes, with weights proportional to the likelihood that the particular cause was assigned to undetermined in the gold standard database. Secondly, this fractional redistribution weight is averaged with a proportional redistribution weight selected according to the Global Burden of Disease age and sex COD distribution for the country. The cause of undetermined deaths is certain deaths (such as pneumonia) this because of inherent more difficulty to diagnose COD using VA methods than a cause like Road traffic accident.

2. **Insilico VA**

The main causes of deaths using InsilicoVA analysis are prematurity (32.9%), birth asphyxia (23.3%), acute respiratory infection including pneumonia (8.7%), neonatal pneumonia (5.1%), and neonatal sepsis (3.5%).

3. **InterVA5**

The main causes of U5M using InterVA5 are; birth asphyxia (19.8%), neonatal pneumonia (15.1%), congenital malformation (14.9%), prematurity (12.1%) and neonatal sepsis (10.9%).

Limitation:

1. Barriers to its use VA by national registration systems are time and cost needed for data collection. a minim duration of four weeks to allow an adequate mourning period. The maximum recall period may vary between different sites from six months to an indefinite amount of time. A long recall

period is likely to impair a respondent's ability to recollect and report relevant information. However, inadequate time for mourning.

2. Administration of open-ended VA questions generally requires medical training to elicit appropriate symptoms and signs that are not reported spontaneously.
3. The questionnaire is little bit long, even after adequate training the minimal required time for filling the questionnaire is about 20-30 minutes, this duration is very long especially with the attention to elicit interviewers to memorize this painful events.
4. The educational background of VA interviewers varied between sites. medical knowledge may bias the result towards certain causes of death familiar to the interviewer.
5. Insufficient or incomplete data, regarding telephone number of the person who report the deaths, death or birth date registration, and incomplete or wrong address of the case reported.
6. The questionnaire need to be modified and updated, this based on our experience and points of views of data collectors.

Points of strength:

1. The questionnaire was written in the local language, although, using a language other than the mother tongue did not affect the sensitivity and specificity of VA.
2. To the best of our knowledge, this study is the first to apply WHO verbal autopsy 1.5.1 tool in Egypt.
3. The research team planning to upload the collected data on ARC-GIS, to do spatial analysis of under-five mortality and make use of the data collected from health records.
4. Wide geographic area covered in this study, with a respected small grant.

CONCLUSION

The current study has shown the following:

- In Alexandria, during the period starting from the 1st of January 2017 till the 30th of June 2019, in 27 health offices, 3064 under-five children died.

Based on death record:

- Neonatal mortality represented 58.3% of all U5M. About 31.7% of children died after the age of 28 days and before the first birthday. Infant mortality was 90% of the U5M.
- Childhood cardiovascular diseases were the most frequently reported causes of U5M, 20.60% followed by preterm delivery 14.73%, pneumonia 11.83%, septic shock 9.71%, and congenital malformation 9.34%.
- The highest U5M was in Montaza District 29.06% (861/2966) (while the lowest mortality was in Gomorok 0.39%, (71/2966) and Borg El-ARab district 5.16% (153/2966).
- The overall U5M was higher in males than females, and within all age categories except (day 7-28 days).
- Early neonatal mortality comprised the majority of these deaths.

Based on VASA analyzed by Smart VA:

- The over-all causes of U5M are preterm delivery, congenital malformation, pneumonia, and neonatal pneumonia.
- The most common causes of child mortality were pneumonia, childhood cardiovascular diseases, digestive diseases and diarrheal dysentery.
- The most common causes of neonatal mortality were preterm delivery, congenital malformation, neonatal pneumonia and birth asphyxia.
- The classification of cause of death by the global burden of diseases board categories revealed that, communicable diseases, maternal, neonatal and nutritional diseases were the main contributors to U5M followed by non-communicable diseases, and injuries.

RECOMMENDATIONS

The following could be recommended from this study:

A) Death registration and use of verbal autopsy:

- Verbal autopsy should be applied in all death cases occurring outside the health facilities.
- Medical students should be trained to fill the death certificates completely and accurately with high focus on the circumstances preceding death.
- Training of the health officers responsible for registering death certificates with initial focus on the basic demographic data related to the deceased such as, address, phone number and relation with the notifier.

B) Health services provided to under-five children:

- Adopt strategies that could reduce or lower the incidence of neonatal pneumonia including vaccination and maternal screening for vaginal infection.
- More vigorous research is required to identify the determinants of the high neonatal mortality.
- Evaluate the role of the integrated management of childhood illness (IMCI) in reducing the mortalities caused by communicable and non-communicable diseases.
- More attention should be directed to antenatal services with introduction of genetic counseling to antenatal services in cases of consanguinity.

C) Future research directions:

- Investigate the role of VA to identify the causes and distribution of maternal mortality.
- More research is needed to investigate the underlying causes of early neonatal mortality and preterm delivery.

APPENDICES

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