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RESEARCH ARTICLE

An Analysis of Health Insurance Data Using the Directed Acyclic Graph: An Application in Nigeria

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Abstract:

Background:

In this study, we used the total amount of insurance claims from patients in Nigeria as the data to investigate the direct and indirect effects of the diagnoses.

Methods:

We applied the Directed Acyclic Graph (DAG) with the total amount of the claims for each month for 89 diagnoses using datasets drawn from private insurance companies in Nigeria from January 2015 to September 2016, which provided 21 records for each diagnosis.

Results:

The result from DAG showed three pairs of direct effects: (1) Absolute Neutrophil Count (ANC) had a direct effect on appendectomy, (2) Sexually Transmitted Infections (STIs) had a direct effect on caesarean section, and (3) Glaucoma had a direct effect on insomnia.

Conclusion:

The most interesting result pertained to the third pair of diagnoses which is pertinent to research worldwide. We not only explored the relationship in a scientific way, but also the direction of the effect provided a basis for recommendations for healthcare in Nigeria and worldwide.

Keywords: Diagnosis, Direct effect, Directed acyclic graph, Glaucoma, Insomnia, Insurance data.

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1. INTRODUCTION

In the present study, the Directed Acyclic Graph (DAG) was used for the first time to analyze health insurance data. The objective was to find relationships between 89 diagnoses in reference to health insurance data from Nigeria. Unlike regression analysis, a classical method was used to explore relationships between variables, and DAG had the key advantage of establishing the direction of the relationships identified.

Established techniques that had been used to analyze insurance data included neural networks [2 - 6], decision tree [7, 8], association rules [9], Bayesian network [10], and genetic algorithms [11, 12]. However, these techniques were used primarily for detecting fraud, not for investigations related to healthcare. In addition, researchers applied other techniques such as naïve Bayes to evaluate the risk to people carrying life insurance [13], association rules, neural segmentation to detect patterns in pathology services ordered, and to classify general practitioners into groups based on the nature and style of their practice [14].

In our application of DAG to health insurance data, the most interesting result in terms of the 89 diagnoses is that glaucoma has a direct effect on insomnia. Research studies have been undertaken worldwide [15 - 25] focusing on relationships between these two symptoms, but most theories have yet to be subjected to adequate scientific testing [26]. In addition to identifying this relationship, we considered possible reasons for it, including the possibility that the medication used to treat glaucoma may cause insomnia, which is covered in the discussion section.

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2. DATASET

This study is based on monthly health insurance data from the information technology department of a local Health Management Organization (HMO) in Nigeria. Covering the period from January 2015 to September 2016, the original data consisted of private insurance company and federal (Nigerian Health Insurance Scheme (NHIS)) records. However, we limited our analysis to the data drawn from the private sector because this sector had a much larger number of claims than the federal sector. It should be noted, however, that we did not have access to demographic information, such as the age and sex of the people who had made the claims.

We summarized the data by finding the total monetary amount of the claims made each month for each diagnosis. Numerous diagnoses had claims totaling less than 100,000 Nigerian Naira for the focal period, and we eliminated these diagnoses from the analysis. For the focal period, one U.S. dollar was equal to 727,415 Naira and 727,776 Naira, in 2015 and 2016, respectively. The diagnoses for each of which all the claims made fell short of 100,000 Nigerian Naira and a few claims with unclear definitions were eliminated. 89 diagnoses remained for the analysis. The variables of interest in our analysis were the total monetary amount of the claims made each month for each of the 89 diagnoses, for which we had monthly data over the 21-months period from January 2015 to September 2016. Therefore, there were 21 observations for 89 variables. The 89 variables considered in the study are listed in Table **1**.

3. MATERIALS AND METHODS

In this study, we focused on exploring the relationship between diagnoses based on insurance data in a scientific way. We were interested in both; discovering any relationship that existed, and determining the directions of those relationships, specifically in regard to the direct and indirect effects of one diagnosis on another.

In this section, we constructed a Directed Acyclic Graph (DAG) (also referred to as a Bayesian network [27, 28]) to help identify the direct and indirect effects between the total monetary amount of the claims each month for each of 89 diagnoses on each other as found in an investigation of private insurance data in Nigeria for the focal period. A number of algorithms exist for constructing DAGs, falling essentially into three categories: Constraint-based algorithms, Greedy Search (GS) algorithms [29], and score-based algorithms [30].

Table 1. Variables representing the total monetary amount of the claims each month for 89 diagnoses.

Variable	Total Amount of Claims each Month for Diagnosis	Variable	Total Amount of Claims each Month for Diagnosis	Variable	Total Amount of Claims each Month for Diagnosis
x1	Abdominal pain	x31	Diarrhoea	x61	Mss pain/myalgia
x2	Allergy	x32	Dyspepsia	x62	Muscle spasms
x3	Amenorrhea	x33	Ear wax impaction	x63	Myopia
x4	Anaemia	x34	Enteritis	x64	Neonatal jaundice
x5	ANC (absolute neutrophil count)	x35	Family planning	x65	Neonatal sepsis
x6	Appendicectomy (appendectomy)	x36	Food poisoning	x66	Normal delivery
x7	Appendicitis	x37	Gastritis	x67	Otitis media
x8	Arthralgia	x38	Gastroenteritis	x68	Ovarian cyst
x9	Arthritis	x39	Gingivitis	x69	Paronychia/whitlow
x10	Asthma	x40	Glaucoma	x70	Pelvic inflammatory disease
x11	Boil/furunculosis	x41	Haemorrhoids	x71	Peptic ulcer disease
x12	Breast lump	x42	Heartburn/GERD	x72	Pharyngitis
x13	Bronchitis	x43	Helminthiasis	x73	Pneumonia
x14	Burns	x44	Hepatitis	x74	Presbyopia
x15	Caesarean section	x45	Hernia	x75	Pterygium
x16	Carbuncle	x46	Hyperemesis gravidarum	x76	Road traffic accident
x17	Cellulitis	x47	Hyperlipidemia	x77	RTI (respiratory tract infection)
x18	Cervical spondylosis	x48	Hypertension	x78	Sepsis
x19	Chicken pox	x49	Immunization	x79	Sprain/fracture
x20	Circumcision/ear piercing	x50	Impetigo	x80	Sexually transmitted infection (STI)
x21	Cold/catarrah	x51	Infertility	x81	Stress
x22	Colitis	x52	Injury	x82	Tension headache
x23	Conjunctivitis	x53	Insomnia	x83	Threatened abortion
x24	Constipation	x54	Lipoma NOS	x84	Tonsilitis
x25	Consultation/review	x55	Lower respiratory tract infection (LRTI)	x85	Typhoid fever/enteric fever
x26	Coryza/allergic rhinitis	x56	Lumbar spondylosis	x86	Urinary tract infection (UTI)
x27	Cyesis	x57	Malaria fever/plasmodiasis	x87	Upper respiratory tract infection (URTI)
x28	Dental caries	x58	Measles	x88	Uterine myoma/fibroid

(Table 1) contd.....

Variable	Total Amount of Claims each Month for Diagnosis	Variable	Total Amount of Claims each Month for Diagnosis	Variable	Total Amount of Claims each Month for Diagnosis
x29	Dermatitis	x59	Menorrhagia	x89	Vaginal candidiasis
x30	Diabetes mellitus	x60	Miscarriage	-	-

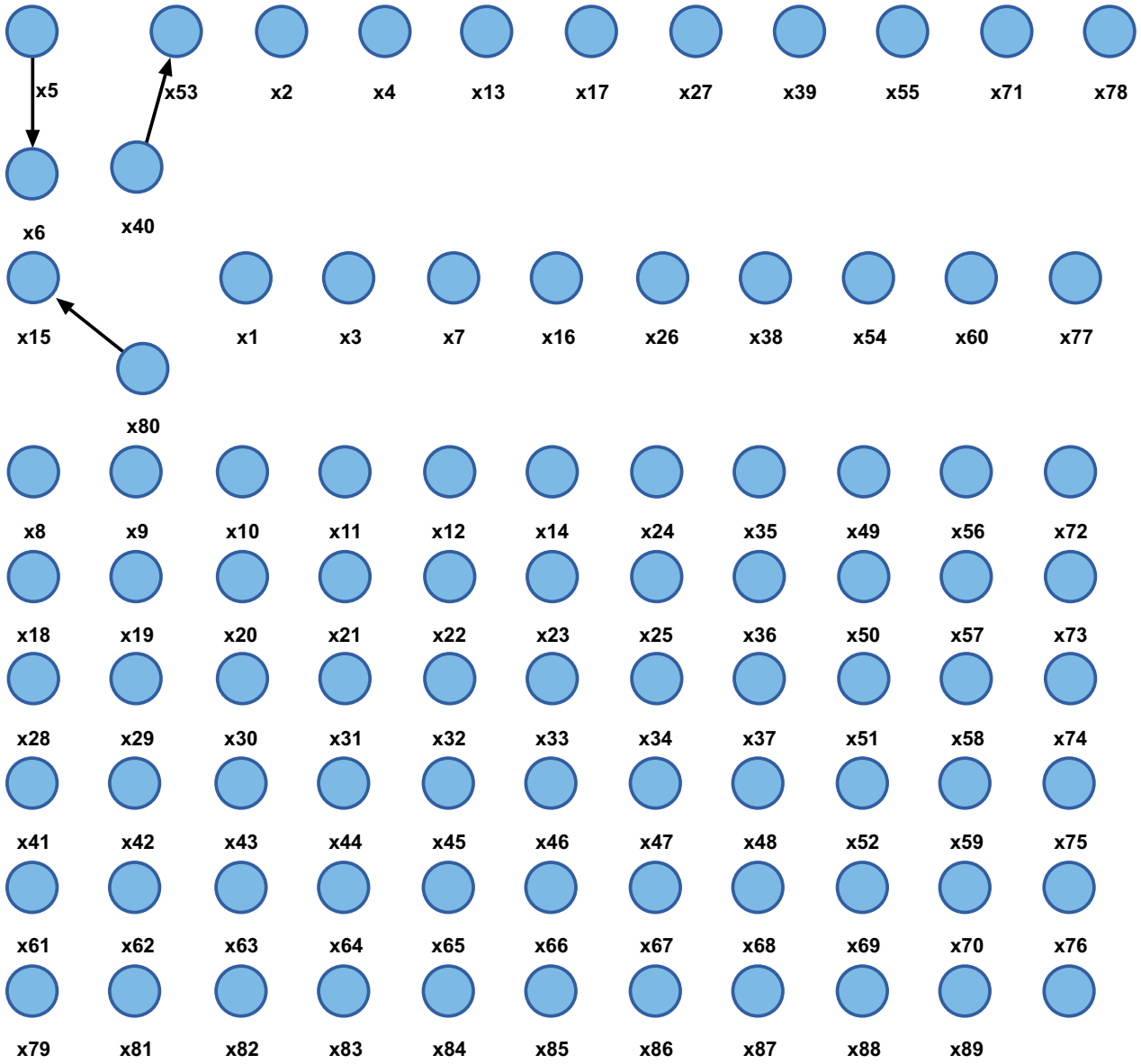

Fig. (1). Directed acyclic graph for 89 variables.

We employed an algorithm implemented by the Bayesialab software (http://www.bayesia.com). Note that all the variables are discretized in the Bayesialab implementation. We tried all the search algorithms available in the Bayesialab software—which included Maximum Spanning Tree, Taboo, EQ, SopEQ, and Taboo Order—and found that they all yielded the same results.

4. RESULTS

Our analysis on the total monetary amount of claims each month for each of the 89 diagnoses are represented by x1–x89. The results from DAG are shown in Fig. (**1**).

In Fig. (**1**), a direct effect is identified for only three pairs of the 89 diagnoses. In the first pair, ANC (absolute neutrophil count) (x5) had a direct effect on appendectomy (x6). In the second pair, STIs (sexually transmitted infections) (x80) had a direct effect on caesarean section (x15). In the third pair, glaucoma (x40) had a direct effect on insomnia (x53).

The relationship between the first pair, ANC and appendectomy, is easily understood given that a high ANC value is an inflammation marker that indicates the need for an

appendectomy procedure [31]. As stated by Al-Gaithy, ANC and the preoperative evaluation of white blood cells (WBCs) are certainly the most widely used references in determining the severity of acute appendicitis [32].

For the second pair, STIs and caesarean section, the relationship can be explained by the recommendation from the Centers for Disease Control and Prevention (CDC) according to which pregnant women who have been diagnosed with an STI should give birth by caesarean section. As indicated in the CDC's treatment guidelines for sexually transmitted diseases, "Cesarean section is recommended for all women in labor with active genital herpes lesions or early symptoms, such as vulvar pain and itching" [33, 34].

For the relationship between the third pair, glaucoma and insomnia, related studies connect Obstructive Sleep Apnea (OSA), a very common sleep disorder, with a number of eye diseases, including glaucoma, the second leading cause of blindness worldwide [26].

5. DISCUSSION

Several studies link OSA to glaucoma. McNab [15] and Robert *et al.* [16] noticed the occurrence of primary open angle glaucoma or POAG, the most common type of glaucoma, in groups of patients with OSA and floppy eyelid syndrome. Further, researchers have shown that this kind of glaucoma co-occurs with OSA [17 - 24]. In these studies, 20 to 57% of the sample of patients with POAG or Normal-Tension Glaucoma (NTG), another common kind of glaucoma, were also diagnosed with OSA. In other studies of patients with OSA, researchers have estimated that 2 to 27% of this population have POAG or NTG, as compared with an estimate of 2% in the general population [24, 26]. In addition, Seixas *et al.* investigated the relationship between visual impairment, insomnia, and anxiety/depression symptoms among Russian immigrants [25]. The results show that after the data were adjusted for the effect of anxiety/depression symptoms, those with a visual impairment were twice as likely as those without a visual impairment to report insomnia.

Most of the previous work has shown that many patients with OSA also have glaucoma. However, none of the work has shown the direction of this relationship.

In this study, the new technique, DAG, is used for the first time in the literature to explore relationships and their directions between diagnoses based on health care insurance data from the private sector in Nigeria in a scientific way. We found that glaucoma had a direct effect on insomnia. With this direction, a factor that may cause a direct effect from glaucoma to insomnia is the medication used for patients with certain kinds of glaucoma. It should be noted, too, that beta-blockers, which are often used to treat glaucoma [35], can cause insomnia [36 - 38].

CONCLUSION

Given the evidence of a relationship between glaucoma and insomnia found in the present study, future research should focus on investigating (i) The prevalence rate of insomnia among patients with glaucoma in Nigeria, (ii) The medication used to treat glaucoma in Nigeria, and (iii) The effects of this medication. Based on this research, physicians who treat patients with glaucoma have a basis for educating patients in regard to possible adverse reactions [35]. Research in this area could be extended to include a consideration of the medication used to treat glaucoma in Nigeria and worldwide.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available from corresponding author [P.C] upon reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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