Identifying Type of Prostate Cancer using Analytic Hierarchy Process

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ABSTRACT

Prostate cancer is one of the most prevalent types of cancer among males where many symptoms are said to be associated with. However, symptoms are a general identification of prostate cancer where most of patients shared the common symptoms, thereby it is difficult to suggest the actual type of prostate cancer. This paper aims to identify the most likely type of prostate cancer using the pair-wise comparison approach of decision making model. The typical types of prostate cancer and its most commonly shared symptoms are defined according to the framework of analytical hierarchy process (AHP). The symptoms of trouble urinating, difficulty starting urine stream, blood in urine and excessive urination at night are the selected criteria of the decision model. Three experts comprise two medical officers and an oncologist were interviewed to provide input data about the association of the common symptoms and types of prostate cancer. The five-step AHP was utilized to establish decision. Based on the common symptoms, the decision model identified prostate cancer of sarcoma is the most likely type of prostate cancer.

Keywords: Prostate cancer, multi-criteria decision making, analytical hierarchy process, pair-wise comparison component.

1. INTRODUCTION

One of the most prevalent deadly diseases that impacted most of the people in the world nowadays is cancer. There are many patients that have been diagnosed with multiple types of cancer worldwide. In Malaysia, the five most frequent types of cancers among males, according to the statistics released in 2007 were lung, colorectal, nasopharynx, prostate and lymphoma, while the five most common cancers among females were breast, colorectal, cervix, ovary and lung [1]. Among Malaysian males, prostate cancer is ranked the fourth prevalent cancer and expected to increase in the future.

Prostate cancer is the development of cancer in the prostate, which is part of the male reproductive system [2]. The incidences of prostate cancer are more prevalent among males aged more than 45 years old. A report also mentioned that environmental and genetic factors may play an important role to the likelihood of prostate cancer [3] and may need some public health intervention. Other that genetic factors, several other factors have shown to be related to prostate cancer, such as socio-demographic, lifestyle, diet, occupational exposure, medical and health status [4].

There are at least three types of prostate cancer that have been known thus far. The American Society of Clinical Oncology noted that adenocarcinoma is the most common type of prostate cancer, accounting for more than 95 percent of prostate cancer cases [5]. According to this article, adenocarcinoma is a type of cancer that begins in the glandular tissue of the prostate cancer. Sarcoma is another type of prostate cancer. An international health care center in the United States of America reports prostatic sarcoma as a rare form of prostate cancer, making up less than 0.1 percent of all prostate cancers.

This type of prostate cancer primarily affects men who are in the age range of 35 to 60 years old. Small cell carcinoma of the prostate is the third type of prostate cancer. It is a pathologic subtype of prostate cancer with unique clinical features which accounts for about 1 percent to 2 percent of malignancies of the prostate gland.

Brownback et al., [6] wrote about small cell carcinoma of the prostate. They report that small cell carcinoma of the prostate is very rare and has been documented in only 150 cases since 1997.

All types of prostate cancer are typically shared almost common symptoms. The most common symptom of prostate cancer is difficulty in urinating. The prostate is located underneath the bladder and surrounds a portion of the urethra, a small tube that carries urine from the bladder out of your body. When the prostate becomes enlarged because of cancerous cell growth, the urethra can be pinched, which can lead to urinary problems. It can be difficult to begin urinating, even if you have a full bladder. Very often, patients with prostate cancer have been engaged with a weak flow of urine when urinating.

The weak flow of urine may prevent patients from fully emptying the bladder. Certain men with prostate cancer experience sensations of burning or pain while urinating that can be accompanied by blood in the urine (hematuria). There are also difficulty starting urine stream (hesitancy) and excessive urination at night (nocturia) [2].

The identification of symptoms for the specific type of prostate cancer is a very tricky process. There is no clear indication to precisely identify the type of prostate cancer just by observing the most common symptoms. In other words, the observed symptoms and types of prostate cancer are the two layers of attributes.
that need to be concurrently considered. Therefore, the multiple symptoms of prostate cancer and its common multiple symptoms can be considered as a multi-criteria decision making (MCDM) problem. It is very difficult to determine type of cancer just based on the observed symptom due to no clear one-to-one mapping between symptom and type of prostate cancer. However, experts’ opinions are definitely very critical in suggesting the type of cancer based on the prevailed symptoms. Many medical decisions depend on collaborative efforts among experts. Consensus opinions really help for identifying the right type of cancer. This paper utilizes experts’ opinions to propose the appropriate type of prostate cancer based on common symptoms using a decision making method of analytic hierarchy process (AHP). The AHP has been applied in many medical and health sciences decisions.

An extensive review was made by Liberatoreand Nydick [7] to showcase applications of the AHP in medical and health care decision making. There are also many medical studies used the AHP to conduct empirical research for specific diseases or health problems. Abdullah and Azmian [8] for example, proposed weight of obesity factors using the AHP. The AHP was also used by Abdullah et al., [9] to measure cancer risks perceived by public. Chung et al., [10] and Dollan [11] applied AHP in prostate cancer diagnosis. The implementation to a public hospital in Malaysia were invited to provide interview with medical experts. The experts comprise two oncologist (E1, E2) and an an oncologist (E3) attached with a public hospital in Malaysia were invited to provide linguistic judgment. The experts need to judge the relative

Section 2 describes a review on AHP. Section 3 presents research framework. The implementation to a case of prostate cancer diagnosis is presented in Section 3. Computational procedures and experimental results are shown in Section 4. Finally, a short conclusion is made in Section 5.

2. A BRIEF REVIEW ON THE AHP

The analytical hierarchy process (AHP) was introduced by Saaty in 1990 as an excellent multi-criteria decision making tool [12],[13]. The main task of the AHP is to propose a decision topolicy so that they can provide solutions to any complex problems by structuring criteria and alternatives hierarchy. It is a mathematical device in multi-criteria decision making which designing the decision factors in a hierarchic problem structure [12],[13]. One of the main advantages of Saaty’s AHP is its simplicity compared to many previous decision support methods. The first level of hierarchy of AHP is defining focus of the problem. Next level comprises multiple criteria that define alternatives. The third level is the contributing alternatives or sometimes can also be known as causes or factors.

The relative importance of criteria and alternatives are evaluated using pairwise comparisons. The results of all pair-wise comparisons is stored in an input matrix $A = a_{ij}$ that is an $n$ by $n$ matrix. The element $a_{ij}$ is the intensity of importance of criterion $n_i$ compared to criterion $n_j$.

The typical set up of matrix to compare each criterion and alternatives is given as

$$A = a_{ij} = \begin{bmatrix}
1 & a_{i1} & \cdots & a_{in} \\
a_{21} & 1 & \cdots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{in} & \cdots & \cdots & 1
\end{bmatrix}$$

$i, j = 1, 2, ..., n$ where $a_{ij}$ is integer and $0 < a < 10$ and $a$ is $a_{ij}$, then $a_{ij} = 1/a$, then $a_{ij} = 1$ if i = j.

Eigenvector is obtained by normalizing the pairwise comparisons. Divide each entry by the total of its column

$$a_{ij} = \frac{p_i}{p_j}$$

$$\frac{p_i}{p_j} = \frac{p_i}{\sum_{j=1}^{n} p_j} = \frac{p_j}{\sum_{j=1}^{n} p_j} = \frac{p_i}{\sum_{j=1}^{n} p_j}$$

Divide total row by the total number of row:

$$\frac{\frac{p_i}{\sum_{j=1}^{n} p_j} + \cdots + \frac{p_i}{\sum_{j=1}^{n} p_j}}{n} = \frac{n p_i}{\sum_{j=1}^{n} p_j} = \frac{p_i}{\sum_{j=1}^{n} p_j}.$$

Weighted performance for each alternative with respect to each criterion and composite priority (priority of overall weights in the entire hierarchy) are obtained using the following equation,

$$w_i = \sum A_i K_{ij}$$

where

$w_i = $ Overall relative rating for factors $i$  
$A_i = $ Average normalized weight for factors $i$  
$K_{ij} = $ Average normalized rating for alternatives $j$ with respect to factors $i$.

The steps are utilized to decide the most preferred alternative in a case study of symptoms that associated with prostate cancer.

3. RESEARCH FRAMEWORK

The research begins by developing AHP questionnaire with the purpose to compare the common symptoms associated with type of prostate cancer. The questionnaire was used as a guideline during personal interview with medical experts. The experts comprise two medical officers (E1, E2) and an oncologist (E3) attached with a public hospital in Malaysia were invited to provide linguistic judgment. The experts need to judge the relative
measurement between the criterion and the alternatives using pair-wise comparison proposed by Saaty [14]. The experts were invited to provide a rating of alternatives with respect to criteria using linguistic expression. For example, the experts provide a rating of the degree of importance for the criterion trouble urinating with respect to blood in urine and to indicate whether they felt that one factor was ‘strongly more important’ or ‘extremely more important’ to another factor on a nine-point degree of preference scale. The scale and the relative importance are presented in Table I.

Table 1: Pair-wise comparison scale

<table>
<thead>
<tr>
<th>Preference on pair-wise comparison</th>
<th>Preference number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equally important</td>
<td>1</td>
</tr>
<tr>
<td>Moderately more important</td>
<td>3</td>
</tr>
<tr>
<td>Strongly more important</td>
<td>5</td>
</tr>
<tr>
<td>Very strong more important</td>
<td>7</td>
</tr>
<tr>
<td>Extremely more important</td>
<td>9</td>
</tr>
<tr>
<td>Intermediate value</td>
<td>2, 4, 6, 8</td>
</tr>
</tbody>
</table>

To identify the type of prostate cancer, criteria and alternatives of the MCDM problem are defined. The alternatives or types of prostate cancer of prostate cancer are ‘Adenocarcinoma’ (A1), ‘Sarcoma’ (A2), and ‘Small cell sarcoma’ (A3). The selected criteria are ‘trouble urinating’ (C1), ‘hesitancy-difficulty starting urine stream’ (C2), ‘hematuria-blood in urine’ (C3), and ‘nocturia-excessive urination at night’ (C4). The hierarchy structure of focus, criteria and alternatives are shown in Figure 1.

![Figure 1: Hierarchy structure of focus, criteria and alternatives](image)

The complex relationship among the types of prostate cancer and the common symptoms are solved using the AHP procedures. Next section presents the computations of the case study using steps of the AHP.

4. COMPUTATION

The following computations are performed using the linguistic judgment data provided by the first expert (E1).

**Step 1: Construct pair-wise comparison**

The pairwise comparison for each criterion and the alternative are shown in Table 2 and Table 3 respectively.

**Table 2: Criteria pairwise comparison using AHP**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>3</td>
<td>1/5</td>
<td>5</td>
</tr>
<tr>
<td>C2</td>
<td>1/3</td>
<td>1</td>
<td>1/3</td>
<td>1/5</td>
</tr>
<tr>
<td>C3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>C4</td>
<td>1/5</td>
<td>5</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>Sum of column</td>
<td>13/2</td>
<td>12</td>
<td>7/4</td>
<td>56/5</td>
</tr>
</tbody>
</table>
Table 3: Alternatives pairwise comparison with respect to each criterion

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>1/5</td>
<td>7</td>
</tr>
<tr>
<td>A1</td>
<td>5</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>A2</td>
<td>7</td>
<td>1/7</td>
<td>1</td>
</tr>
<tr>
<td>A3</td>
<td>1/7</td>
<td>1/7</td>
<td>1</td>
</tr>
<tr>
<td>Sum of column</td>
<td>43/7</td>
<td>4/3</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>1</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>A1</td>
<td>1/7</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>A2</td>
<td>1/5</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>A3</td>
<td>1/5</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>Sum of column</td>
<td>4/3</td>
<td>4/15</td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3</td>
<td>1</td>
<td>1/5</td>
<td>1/3</td>
</tr>
<tr>
<td>A1</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>A2</td>
<td>3</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>A3</td>
<td>3</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>Sum of column</td>
<td>9</td>
<td>7/5</td>
<td>19/3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4</td>
<td>1</td>
<td>3</td>
<td>5/3</td>
</tr>
<tr>
<td>A1</td>
<td>1/3</td>
<td>1</td>
<td>5/3</td>
</tr>
<tr>
<td>A2</td>
<td>5</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>A3</td>
<td>5</td>
<td>1/5</td>
<td>1</td>
</tr>
<tr>
<td>Sum of column</td>
<td>19/3</td>
<td>21/5</td>
<td>31/5</td>
</tr>
</tbody>
</table>

Step 2: Compute priority weight for each criterion.

Priority weight for C1, for example, is computed as,

\[
C1 = \frac{4}{13/2 + 12 + 1/5 + 5/36 + 5} = 0.2412
\]

Similarly, priority weights for C2, C3, and C4 are obtained with the similar computation. Therefore, C2 = 0.0861, C3 = 0.5097 and C4 = 0.1630.

Step 3: Compute the priority weight for the hierarchy of alternatives with respect to each criterion

For example, the priority weight of A1 with respect to C1 is given as,

\[
A1 = \frac{3}{43/7 + 12 + 7/4 + 15} = \frac{3}{2595}
\]

With the similar calculation,

A2 = 0.6751, A3 = 0.0654.

With respect to C2,

A1 = 0.6843, A2 = 0.2276, A3 = 0.0881.

With respect to C3,

A1 = 0.1022, A2 = 0.6864, A3 = 0.2114.

With respect to C4,

A1 = 0.3015, A2 = 0.3657, A3 = 0.3328.

Hence,

W_{C1} = [0.2595, 0.6571, 0.0654]^T

W_{C2} = [0.6843, 0.2276, 0.0881]^T

W_{C3} = [0.1022, 0.6864, 0.2114]^T

W_{C4} = [0.3015, 0.3657, 0.3328]^T

Step 4: Compute the weighted performance for each alternative with respect to each criterion.

Weighted performance of alternative A1 with respect to C1 is given as,

A1 = 0.2595(0.2412) = 0.0626,

A2 = 0.1628,

A3 = 0.0158.

Similarly, A2 with respect to C2

A1 = 0.0589,

A2 = 0.0196,

A3 = 0.0076.

A3 with respect to C3

A1 = 0.0521,

A2 = 0.3499,

A3 = 0.1077.

A4 with respect to C4

A1 = 0.0491,

A2 = 0.0596,

A3 = 0.0542.

Step 5: Compute the composite priority (priority of overall weights in the entire hierarchy) and ranking the alternatives

A1 = 0.0626 + 0.0589 + 0.0521 + 0.0491 = 0.2228,

A2 = 0.5919,

A3 = 0.1853.

The similar computations are applied for the linguistic data provided by E2 and E3.
Composite priority weights obtained from E2 and E3 are 

\[
A_1 = 0.6136, \quad A_2 = 0.2691, \quad A_3 = 0.1173 \quad \text{and} \quad A_1 = 0.4507, \\
A_2 = 0.4325, \quad A_3 = 0.1167 \text{ respectively.}
\]

The final priority weight for each alternative is obtained by averaging all the priority weights. Table 4 shows the weights and ranking for alternatives.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Priority</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0.4290</td>
<td>2</td>
</tr>
<tr>
<td>A2</td>
<td>0.4312</td>
<td>1</td>
</tr>
<tr>
<td>A3</td>
<td>0.1398</td>
<td>3</td>
</tr>
</tbody>
</table>

Based on the contributing symptoms of prostate cancer, the AHP successfully identified sarcoma (A2) as the most possible type of prostate cancer.

5. CONCLUSION

Very often, medical experts have been experienced with problems for identifying specific disease due to multiple common symptoms that could be shared to one specific disease. This paper has developed decision using the multi-criteria decision making model of the AHP that characterized with pair-wise comparison. The most common symptoms that lead to several types of prostate cancer were defined prior to computing linguistic data with the AHP. This paper mainly focused in establishing the weight of types of prostate cancer using the AHP. The decision model was utilized to overcome medical experts’ predicaments in identifying type of prostate cancer. The AHP used five-step computation with the ultimate aim to establish the relative weights of alternatives. The model has successfully identified ‘sarcoma’ as the highest probable type of prostate cancer based on the highest relative weights among alternatives.

However, the result is subjected to further investigation especially in dealing with validity and veracity of the model. Further research could be undertaken to ascertain the results.

REFERENCES


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