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ORIGINAL ARTICLE

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A decision support system to determine the amount of wergild and compensation based on forensic medicine clinical examinations

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Abstract

Background Forensic medicine is crucial in ensuring that the law and justice are carried out as swiftly, effectively, clearly, and accurately as possible. The significant number and interactions of forensic clinical examination variables, the complexity of their differentiation, and the existence of multiple decision-making paths can lead to erroneous decisions that cause irreparable harm to individuals and society. This study aimed to develop and evaluate a decision support system for determining the amount of wergild and compensation based on forensic medicine clinical examinations and the severity of the patient's injury.

Methods A total of 264 data elements and decision-making rules were identified based on an analysis of information sources and focus group discussions. In addition, a decision tree was used to organize the decision-making rules. Then, a system was developed using algorithms for intelligent decision-making. We included 500 patients in our analysis. This system was ultimately evaluated based on the following criteria: precision and accuracy, sensitivity, specificity, usability, and documentation quality.

Results The results indicated that the precision and accuracy, sensitivity, and specificity of the system were 100%. Furthermore, the documentation quality (completeness) increased from 78.2 to 100%. The average score for system usability was 4.35 out of 5, indicating a highly acceptable range.

Conclusion The designed system was effective and beneficial for forensic clinical examinations and quantifying physical damage (wergild and compensation). Therefore, this system can be utilized in forensic medicine's administrative and clinical processes, and its production and commercialization will result in an adequate market penetration rate. In addition, this will empower forensic medicine physicians and reduce decision-making errors.

Keywords Decision support system, Clinical examinations, Forensic medicine, Physical damage, Wergild, Compensation

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Graphical Abstract

Background

Forensic medicine is one of criminal and judicial science's most prominent and essential components (Fang et al. 2020). Forensic science is a bridge between medical science and legal science, where it utilizes various medical sciences to uncover facts and administer justice. Forensic medicine is responsible for eliminating ambiguity in legal proceedings (Bell et al. 2018; Kelty et al. 2018). The significance of forensic medicine is such that approximately one-third of ambiguities in court cases can be resolved with its assistance. The clinical examination area, deceased and autopsy area, and forensic laboratory area are the three areas that define forensic medicine activities (Eraña-Rojas et al. 2019). Individuals who have been assaulted or injured in any way are referred to the general clinical examination division of forensic medicine to determine the legitimacy or invalidity of their claim (Meilia et al. 2020). According to the statistics, approximately 85% of the cases referred to this department involve injuries caused by accidents and conflicts, as well as resolving ambiguities such as determining the extent of the injury and the amount of compensation and disability (Schmidt et al. 2020).

Instructions and guidelines address the significant number and interactions of clinical examination variables in forensic medical decisions, the complexity of their differentiation, and the existence of multiple decision-making paths in this field. They can lead to an increase in erroneous examinations and decision-making errors (Siddaway et al. 2020). Given that legal doctors are utilized and given priority in the criminal justice system and that the Judicial Council considers the Forensic Medicine Organization's opinion, any errors in forensic medicine's examinations and decisions can result in irreparable harm to both individuals and society (Aktas et al. 2018).

With the assistance of human resources, information technology has had a significant impact on facilitating and accelerating affairs in the modern world; forensic medicine is the field that has effectively utilized the knowledge and advanced technology (Torab-Miandoab et al. 2023). Since more than a decade ago, advanced technologies have assisted forensic science in efficiently resolving the mysteries and complexities that arise in this field (Khanagar et al. 2021). Decision support systems in legal fields can promote continuous decision-making, lead to decisiveness in the justice system with transparent legal decisions, and aid in resolving disputes. This is given that forensic decisions are governed by the laws and instructions outlined in the pertinent guidelines. Because forensic decisions involve the relevant policies' laws, and procedures, experts in this field also base their decisions on these laws. Therefore, in most countries today, forensic medicine uses new and emerging technologies, including decision-support systems, and there is a greater need to design and supply decision-support systems (Coelho et al. 2020). Decision support systems are systems that provide alternative solutions to help solve semi-structured or unstructured problems (Torab-Miandoab et al. 2020; Nisioti et al. 2021; Nazir et al. 2018).

Forensic affairs have expanded and developed into vast domains, necessitating active forensic personnel's use of up-to-date information and communication technologies to organize their performance consistently and precisely (Arshad et al. 2018). The explosive growth of forensic information heightens the need for innovative methods to manage and gain data access (Montasari and Hill 2019). Considering the need for forensic experts, judges, and law enforcement professionals to acquire and apply current knowledge of forensic medicine to make expert opinions more scientific in this field, the continuous use of information systems such as decision-making is crucial (Horsman 2019).

Due to the significance of forensic medicine and the implications of its decisions, on the one hand, and the expansion of knowledge and the complexity of decision-making in the field of forensic examinations, on the other hand, the use of information systems, particularly decision support systems, has gained significant importance. Because of the limited number of forensic experts and their unequal distribution across the country, in some provinces, no forensic experts are working in the medical organization, and general physicians are also used in these centers. The organization's managers emphasize using auxiliary systems in the complex, cognitive, and time-consuming process of forensic medical decision-making. Currently, such systems do not exist or are not used by the nation's forensic medicine organization (Cherrington et al. 2020; Haines et al. 2018).

To this end, the current study aimed to design and evaluate the decision support system of forensic medical examinations so that forensic doctors can perform forensic medical examinations more quickly, accurately, and appropriately using this system, thereby improving decision-making (determining the amount of wergild and compensation).

Methods

The study employed a descriptive-developmental approach conducted in three phases: descriptive, developmental, and evaluative. Pre-existing methods from the field were adopted and customized for each phase. The research environment during the descriptive and developmental phases was the Health Information Technology Laboratory of the Faculty of Medical Information and Management in Tabriz University of Medical Sciences, while the evaluation phase took place at the General Forensic Medicine Department of the East Azerbaijan province.

In the descriptive study phase, a review of published literature and gray sources from global websites specializing in forensic medicine was conducted to identify information needs, data elements, and guidelines for forensic clinical examination protocols and related decision-making. Additionally, three 2-h focus group meetings were held with 9 experts in forensic medicine, health information management and medical informatics. The purposive sampling method was used to identify recognized experts. Potential experts were identified from publications on forensic medicine and health information systems in databases. The experts were eligible to participate in focus group meetings if they were specialists in health information management, health information technology, forensic medicine, and medical informatics and had a work experience of 5 years or more in related field, had at least 5 articles on health information systems or forensic medicine within the last 10 years, and also lived in Tabriz-Iran.

During the first session, the items extracted in the form of a checklist, which was set on a five-point Likert scale from very important to not important, were provided to the members of the focus group for review, and the items that received scores of important and very important were approved. At the following meeting, information requirements and data elements were extracted from confirmed cases. In the subsequent step, another meeting was held with the selected team members to determine the decision-making algorithms (decision-making model). Thus, all types of injuries were categorized and then a certain amount of compensation and wergild was determined for each of them. The decision-making model was determined based on the results of the previous studies and the software yEd Graph Editor. All cases were examined using qualitative analysis.

During the development study phase, existing architectures used in decision support systems were examined and a new architecture was implemented, incorporating modern technologies and intelligentization methods. Scrum approach of agile methodology was used to develop the system based on the intelligentization methods, decision tree algorithm, and framework determined in the previous phase, and its results were presented based on the architecture and design procedure. In the current research, rule-based reasoning forms the decision points of forensic clinical examinations and physical damage determination based on the if-then representation of previously extracted knowledge. In this phase, MVC (Model-View-Controller) Core technology, a database utilizing MongoDB (Database) and SQL (Structured

Query Language) server software, system logic employing Visual Studio software, the Asp.net core 5 integrated environment, and Ajax, Java, and C# programming languages. The system's user interface was developed using Visual Studio and HTML (HyperText Markup Language), CSS (cascading style sheets), and bootstrap programming languages in a bilingual format (English and Persian). In this phase, data analysis methods are not applicable.

In the evaluation study phase, the designed system was subjected to the opinions and votes of users (legal doctors) and evaluated using the System Usability Scale tool and the key indicators of accuracy and precision, sensitivity, specificity, applicability, and documentation quality (completeness).

Files of all patients referred to the General Department of Forensic Medicine of East Azerbaijan Province (Tabriz, Iran) from April 2022 to August 2022 during the shift of forensic doctors collaborating in the research were included in the dataset. There were no exclusion criteria at this stage. The co-legal physician recorded the data simultaneously on paper-based forms and in the smart system, and the results of the system's decisions were compared to the outcomes of expert doctors' decisions. Notably, this system is intended for the forensic doctor who examines the patient and investigates his case; therefore, the patient's information will be accessible only to the forensic doctor conducting the investigation and will not be shared with any other parties. Consequently, it can be concluded that the privacy and secrecy of patient information will be fully maintained. Due to the reasons above, there is no need to obtain informed consent from the people referring to the forensic organization, as their information was not included in the study phase, and the objective was to evaluate the system's functionality.

The evaluation of the smart system was based on the final data set of 500 cases and the SUS (System Usability Scale) questionnaire completed by the relevant experts. A confusion matrix was used to accurately evaluate the system's classification and decision-making model, where the relevant process is the opinion of a gold-standard forensic doctor. Accuracy, sensitivity, and specificity were determined using the following equations: TP denotes the true positive rate, TN represents the true negative rate, FP denotes the false positive rate, and FN is the false negative rate.

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}}(\%) \quad \text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}}(\%)$$

$$Accuracy = \frac{TP + TN}{Total}(\%)$$

Two evaluators (collaborating forensic doctor in the research) assessed the completeness of the paper documents and determined the number and distribution of complete or incomplete records. A document was deemed incomplete if it was missing one or more pieces of data in any format. The following equations were used to calculate the completeness of the documentation:

$$Completeness = \frac{Totalcompleterecords}{Totalrecords}(\%),$$
$$Incompleteness = ((1 - completenes) \times 100)\%.$$

The confusion matrix and Microsoft Excel software were used for statistical analysis in system evaluation.

Results

In this study, 57.14% of the focus group members were forensic experts, while 42.86% were technical experts (health information management, health information technology, and medical informatics). Furthermore, 57.14% of the participants were employed by a forensic organization, while a university employed 42.86%. Moreover, 57.14% had over 5 years of professional experience. The characteristics and qualifications of the participants in the focus group sessions are listed in Table 1.

The extraction of 264 data elements (decision-making protocols according to types of physical damage based on forensic clinical examinations) was performed. As shown in Table 2, the lower limb was the most organized, with 36 categories, whereas psycho-behavioral disorders and burns were the least organized, with two categories each. In addition, the categories of hearing loss in one ear and lower limb fractures had the most data elements with 55 elements, whereas the organ defects caused by pericardial diseases had the least with one element. The determined functional and non-functional system requirements are also shown in Table 3.

The extracted rules, which included 1420 RBR (Rule-Based Reasoning) methodologies, were created in the rule-based engine and used to calculate wergild and compensation based on forensic medicine clinical examinations. A part of the knowledge representation process is depicted as a decision tree in Fig. 1.

This study utilized a comprehensive architecture. The architecture consists of seven major components: user- and case-specific data, a database, a rule base, an inference engine, an explanation system, an editor for the rule base, and a user interface. Figure 2 illustrates the system's architecture.

The registration and login module is the first system module. This module has a fixed access level for forensic data entry specialists. First, the forensic physician registers and enters his information into the system. Next, they log into the system using the established username and password. The next module is the decision support module of the system, in which

Table 1 Characteristics of study participants

Items		Frequency	Percentage
Gender	Male	6	85.71
	Female	1	14.29
Age	20–30	1	14.29
	30–40	3	42.855
	40–50	3	42.855
	> 50	0	0
Academic background	Bachelor's degree	0	0
	Master's degree	1	14.29
	P.H.D	6	85.71
Organization	Hospital	0	0
	Company	0	0
	University	3	42.86
	Forensic medicine organization	4	57.14
Job experience	Less than 5 years	3	42.86
	6–10	2	28.57
	11–15	2	28.57
	More than 15 years	0	0

the forensic doctor selects the injured organ or system based on the anatomical position, and at each stage of clinical examination, they select the results of the clinical examination in the system, and finally, based on the amount of injuries and damages selected in the system and also based on the decision rules of the system, the system suggests the final decision on the amount of compensation and wergild) Based on the decision rules extracted in the descriptive phase, a certain amount of compensation and wergild has been determined for each injury and damage depending on its type(. After proposing a decision from the system, the forensic doctor can either approve the system's proposed decision or modify the decision. In addition, an output of the examination result and the amount of compensation and wergild is produced at the end of the process. The system guides the user throughout all stages of decision-making regarding available instructions and rules. The system is designed bilingually in English and Persian. Figure 3 depicts the system's decision-making module.

From April 1401 to August 1401, 500 patient files were submitted to the General Department of Forensic Medicine of East Azerbaijan Province (Tabriz, Iran) as part of the evaluation phase data. Among the investigated cases, 59.6% were related to men and 40.4% were related to women. Also, 42% of them were married and 58% were single. Their average age was 29.61 years. Also, most of them had basic education or were illiterate.

The evaluation of the system's accuracy, sensitivity, and specificity revealed that its accuracy, sensitivity, and specificity were 100% (Table 4). Comparing the traditional method to using the system indicated that among the 500 records collected using the system, the documentation of all 500 cases (100%) was also complete, whereas using the traditional method, only 391 cases (78.2%) were complete, and 109 contained one or more incomplete items.

Table 5 displays the results of the SUS evaluation conducted by the relevant experts. The average score for the system's usability was 4.35 out of 5, indicating its excellent usability. In addition, according to the evaluators, the system improves forensic physicians' concentration during clinical examinations and greatly assists physicians with examination and decision-making.

Discussion

The current study used an intelligent decision support system to determine the amount of physical injury wergild and compensation based on forensic clinical examinations. Based on forensic clinical examinations, 264 data elements and information required for determining protocols appropriate to physical injuries were identified. The primary task in data collection is identifying and determining information needs and data elements for information systems to function properly (Akbari et al. 2022).

According to the review of studies conducted in this research, there is no uniform standard or format for collecting data in this field in Iran. As a result, determining the information needs and data elements is required to specify the protocols of the decision-making system in Iran for determining the amount of physical damage

Table 2 Information requirements and data elements of the decision support system for determining the amount of wergild and compensation based on forensic medical exams

Body organs/systems	Classification of injuries and injuries	Frequency of data elements
Chest	Injuries and damages of the cardiovascular system	7
	Chest and respiratory system injuries	15
	Organ defects caused by pericardial diseases	1
	Organ defects caused by damage and lesions of the aorta	3
	Organ defects caused by damage to blood vessels and lymphatic system	3
	Organ defects caused by mastectomy (breast glands)	5
Digestive system	Tongue and mouth injuries	3
	Abdominal injuries and injuries	24
	Organ defects caused by swallowing and chewing disorders	3
	Organ defects caused by disorders of the upper part of the digestive system (esophagus, stomach, small intestine, pancreas)	4
	Organ defects caused by colon and rectal disorders	4
	Organ defects caused by anal disorders	3
	Organ defects caused by nervous disorders in stool control	3
	Organ defects caused by bile duct disorders	4
	Organ defects caused by liver disorders	4
Urinary and reproductive system	Kidney injuries and damage	9
	Injuries and damages to the reproductive system of women	6
	Injuries and damages to male reproductive system	10
	Organ defects caused by disorders of the urinary system (bladder, neurological disorders of urinary control and urethra)	16
	Organ defects caused by disorders of the female reproductive system (vulva and vagina, sexual function, cervix and uterus, ovaries and fallopian tubes)	11
	Organ defects caused by disorders of the male reproductive system, sexual function, penis, scrotum, testicles, epididymis and spermatic cord, prostate, and seminal vesicle)	16
Skin and hair	Injuries and damages related to hair	3
	Organic defects caused by skin disorders	5
	Organ defects caused by sensory dysfunction of the skin with a non-dermatomy pattern	3
Endocrine system	Injuries and damages to glands (thyroid, pancreas, adrenal, parathyroid, pituitary)	6
	Organ defects caused by endocrine disorders	4
	Organ defects caused by type 1 diabetes	3
Ear, throat and nose	Injuries and damages to the ear area	11
	The degree of hearing loss in one ear	55
	Organ defects caused by balance disorders (vertigo)	5
	An organic defect caused by the change and malformation of the face in the area under the eyebrow	8
	An organic defect caused by change and deformity in the areas above the eyebrows and under the lip	3
	Non-clinical fracture of facial bones	5
	Injuries and damages to the nose	7
	Organ defects caused by airway disorders	5
	Organic defects caused by smell and taste disorders	2
	Physical defects caused by speech disorders	5
Visual system	Eye injuries and damage	17
	Organic defects caused by anatomical or structural defects of the eye	6
	The percentage of vision loss	23
	Visual impairment caused by visual field disorders	5

Table 2 (continued)

Body organs/systems	Classification of injuries and injuries	Frequency of data elements
Central and peripheral nervous system	Central nervous system injuries and damages	14
	Organ defects caused by structural-anatomical disorders of the central nervous system	7
	Organic defects caused by disorders of the level of consciousness	4
	Organ defects caused by seizure disorders of consciousness (convulsive disorders)	4
	Organic defects caused by high brain function disorders	7
	Physical defects caused by impaired communication skills	5
	Organ defects caused by cranial nerve disorders	28
	Organ defects caused by central disorders of the lower limbs and trunk	4
	Organ defects caused by central disorders of one of the upper organs	4
	Organ defects caused by central disorders of both upper limbs	3
Psychological-behavioral disorders	Physical defects caused by mental-behavioral disorders	5
	Organic defects caused by mental-behavioral disorders	5
Spinal cord	Spine injuries	8
	Organ defects caused by nervous disorders of the respiratory system	4
	Organic defects caused by intervertebral disc herniation in the lumbar region	5
Upper limb	Amputation in the upper limb	22
	Upper limb fractures	32
	Dislocation of upper limb joints	15
	Limb disability related to limitation of movement of the shoulder joint	18
	Limb defects related to stiffness (ankylosis) of the shoulder joint	9
	Limb disability related to the limitation of elbow joint movement	14
	Defects related to stiffness (ankylosis) of the elbow joint	6
	Limb disability related to wrist movement limitation	11
	Limb disability related to stiffness (ankylosis) of the wrist	6
	Limb disability related to limitation of thumb movement	26
	Defects related to stiffness (ankylosis) of various joints of the thumb	15
	Limb defect related to the restriction of movement of the mcp joint of the second or third finger	7
	Limb defects related to stiffness (ankylosis) of the mcp joint of the second or third finger	6
	Limb disability related to the restriction of movement of the pip joint of the second or third finger	6
	Limb defects related to stiffness (ankylosis) of the pip joint of the second or third finger	5
	Limb defect related to movement limitation of the dip joint of the second or third finger	6
	Limb defects related to stiffness (ankylosis) of the dip joint of the second or third finger	5
	Limb disability related to the restriction of movement of the mcp joint of the fourth or fifth finger	8
	Limb defects related to stiffness (ankylosis) of the mcp joint of the fourth or fifth finger	6
	Limb disability related to the restriction of movement of the pip joint of the fourth or fifth finger	6
	Limb defects related to stiffness (ankylosis) of the pip joint of the fourth or fifth finger	5
	Limb disability related to the restriction of movement of the dip joint of the fourth or fifth finger	6
	Limb defects related to stiffness (ankylosis) of the dip joint of the fourth or fifth finger	5
	Impairment of the motor organ of the upper limbs caused by damage to the central nerves	5
	Limb defects caused by damage to nerve roots in the upper limb	5
	Limb defects caused by brachial plexus damage in the upper limb	4
	Limb defects caused by damage to nerve trunks in the upper limb	12
	Grading of upper limb muscle function	6

Table 2 (continued)

Body organs/systems	Classification of injuries and injuries	Frequency of data elements
	Sensory impairment not related to a specific nerve or nerve root in the upper limb	6
	Joint replacement defect in the upper limb	5
	Complications and functional organ defects caused by Sudeck's atrophy in the upper limb	2
	Complications and functional organ defects caused by lymphatic vascular damage in the upper limb	2
	Limb defect, upper limb dysfunction caused by Sudeck's atrophy/vascular damage/Volkmann syndrome	5
	Complications and disability of chronic osteomyelitis in the upper limb	2
	Some injuries/complications in the upper limbs	48
Lower limb	Amputation in the lower limb	23
	Lower limb fractures	55
	Dislocation/diastasis of lower limb joints	13
	Guide to the interference of types of organ defects in the lower limb	11
	Limb defects related to the difference in the length of the two lower limbs	5
	Limb defects related to femoral-pelvic joint movement limitation	21
	Defects related to the stiffness (ankylosis) of the hip joint	22
	Limb disability related to movement limitation and knee deformity	12
	Defects related to stiffness (ankylosis) of the knee joint	12
	Limb disability related to limited ankle movement	19
	Limb defect related to ankle stiffness (ankylosis)	20
	Limb disability related to the limitation of movement of the toes	6
	Limb defect related to ankylosis of the toes	3
	Complications and defects of small organs (muscular atrophy) in the lower limbs	2
	Dysfunction caused by unilateral lower limb muscle atrophy	8
	Impairment of lower limb dysfunction caused by damage to the central nerves	6
	Limb defect, lower limb dysfunction caused by one-sided damage of nerve roots	6
	Impaired organ dysfunction caused by damage to the peripheral nerves of the lower limb	14
	Classification of lower limb muscle function	6
	Sensory impairment not related to a specific nerve or nerve root in the lower limb	5
	Limb defects related to angulation or malrotation at the fracture site of the lower limb	13
	Defects of joint misalignment in the fracture extended to the joint surface	7
	Compensation of the base related to the defect of the replacement organ (total or partial) of the femoral-pelvic joint	3
	Advanced compensation related to the defect of the replacement organ (total or partial) of the femoral-pelvic joint	6
	Compensation of the base related to the defect of replacement (total or partial) of the knee joint	3
	Advanced compensation related to the defect of the replacement organ (total or partial) of the knee joint	7
	Compensation soft tissue injuries of the knee	6
	Limb defects related to meniscectomy or knee laxity following injury or Ligament dysfunction	6
	Complications and disability of osteoarthritis in the lower limb	2
	Limb defects related to osteoarthritis of lower limb joints	14
	Limb defects related to osteoarthritis of lower limb joints	15
	Complications and functional organ defects caused by Sudeck's atrophy in the lower limb	5
	Complications and functional organ defects caused by lymphatic vascular damage in the lower limb	5

Table 2 (continued)

Body organs/systems	Classification of injuries and injuries	Frequency of data elements
	Organ defect, dysfunction of the lower limb caused by Sudeck's atrophy/ lymphatic vascular damage/Volkmann's syndrome/gait disorder	6
	Complications and disability of chronic osteomyelitis in the lower limb	5
	Compensation of some injuries/complications in the lower body	41
Wergilds	Wergild of hair	12
	Wergild of eye	9
	Wergild of nose	11
	Wergild of ear	10
	Wergild of oral areas (lips, tongue and teeth)	35
	Wergild of neck	8
	Wergild of jaw	6
	Wergild of hand and leg	18
	Wergild of nail	2
	Wergild of vertebral column	6
	Wergild of spinal cord	3
	Wergild of testicle	5
	Wergild of rib	2
	Wergild of bone under the neck	3
	Wergild of residence	5
	Wergild of bones	6
	Wergild of intellect	5
	Wergild of hearing	11
	Wergild of vision	5
	Wergild of smell	7
	Wergild of taste	4
	Wergild of voice and speech	4
	Wergild of loss of interest	13
	Wergild of injuries	9
	Wergild of injuries that enter the human body	11
Burning	Burns on the face and neck	4
	Burns in other parts of the body	4

based on forensic clinical examinations. Defining and implementing data elements for collecting required data, determining the appropriate protocol and system performance, uniformity of reporting methods, interoperability of reported results, improved report comparison, providing a guide for future research, and fostering knowledge production. It is performed on demand (Jason et al. 2012). The current study includes all cases. Collecting relevant data elements at the point of clinical examination and decision-making aids forensic physicians, ultimately leading to improved interoperability (Ahmadi et al. 2014).

This study described the framework and decision-making model of the system using the decision tree model. A decision tree is a graphical representation of a decision process or series of decisions; this is a decision-making tool consisting of a graph or tree-like model that depicts decisions and their potential outcomes. The obtained predictions in each decision tree model represent the laws and rules based on which the decision maker makes their decisions (Li et al. 2022). All activities and actions performed by people or systems in all fields result from decision-making, and correct and appropriate decision-making is especially important in forensic medicine. Consequently, the decision-making process is primarily based on the model. When making decisions, the goal is to use models to arrive at the best possible decision (Earwaker et al. 2020).

Decision support systems can be viewed as a collection that is fully compatible with business intelligence. This study utilized a business intelligence approach involving knowledge discovery and visualization techniques to provide a comprehensive view of business

Table 3 Functional and non-functional requirements of the decision support system for determining the amount of wergild and compensation based on forensic medical exams

System performance requirements	Non-functional requirements of the system
Registering and registering user information in the system	Security
Login to the system with username and password	Scalability
Select the affected organ or system or device graphically with anatomical position in the first step	Support capability
Guidance on instructions and notes at each step	Function
The system is web-based	Reliability
Follow the decision paths by clicking on the results of clinical examinations	Usability
Ability to get output from the system	Usability
The ability to see the path taken to reach a decision	Availability
The ability to manage the user panel	Integrity
Ability to communicate with system support	Flexibility
Existence of damage classification based on member or system or device and type of damage	Portable
	Privacy protection

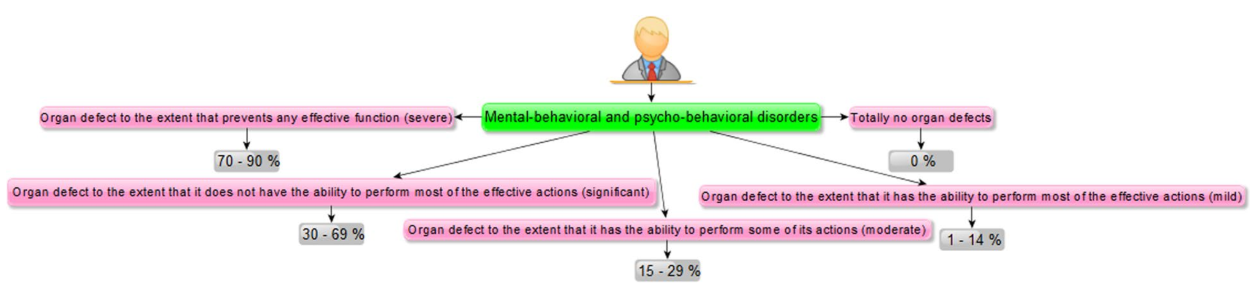

Fig. 1 A part of the decision-making rules framework

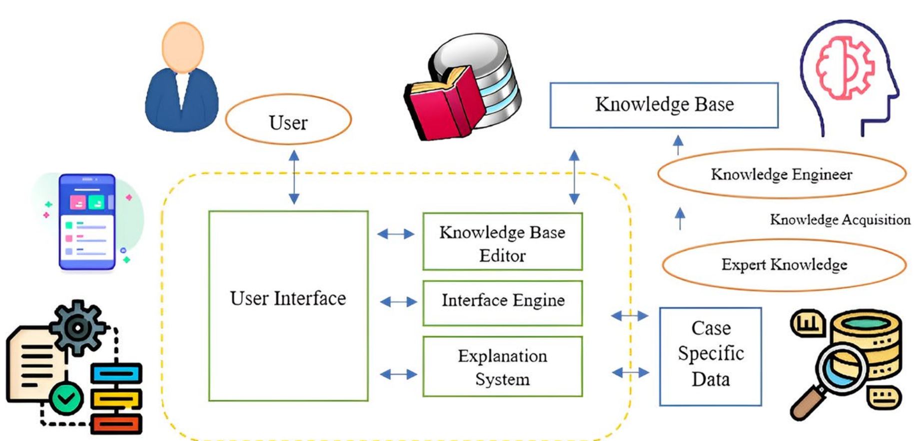

Fig. 2 The architecture used in the system

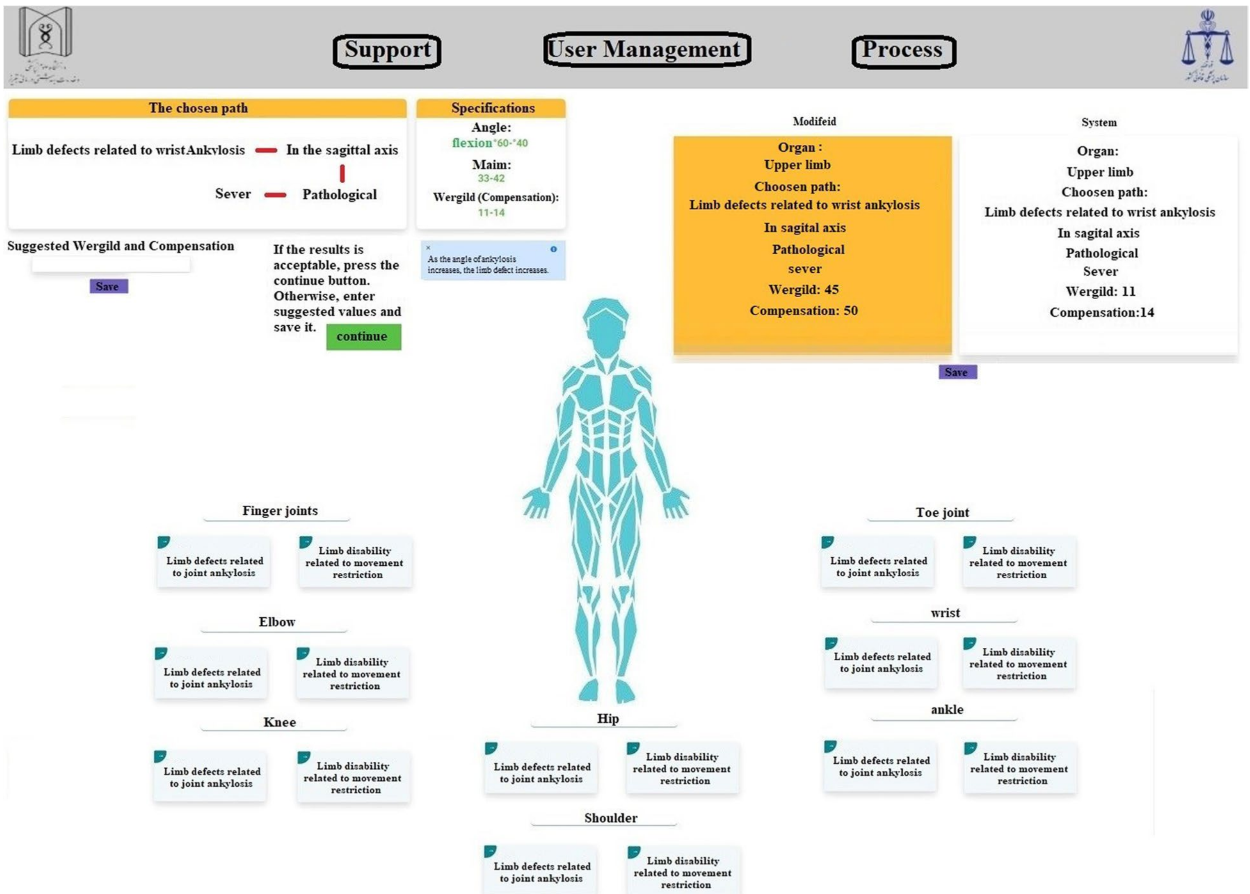

Fig. 3 Decision support module of the system

Table 4 Confusion matrix for the rule-based reasoning model used to determine the amount of wergild and compensation

	System		
		True	False
Forensic doctor	True	500	0
	False	0	0

Table 5 the system's usability score

Checked items	Score system	Degree
Interest in reuse	5	A$^+$
Ease of use	5	A$^+$
Self-study and fast learning	5	A$^+$
The existence of different functions	4	A
Integrity	4.1	A
User satisfaction	4	A
Efficiency and effectiveness	5	A$^+$
Fault tolerance	3.98	A$^-$
Ability to remember	4.11	A
Attractiveness	3.33	A$^-$

intelligence in determining the amount of wergild and compensation based on forensic medicine clinical examinations. Business intelligence tools are utilized to collect, analyze, and disseminate data so that knowledge workers can make informed decisions. Integrating business intelligence tools, such as decision support systems, can improve data analysis and decision support issues (Bhattad and Jain 2020).

Most forensic medicine and medical informatics studies are utilized in crimes, murders, and suicides to identify the victims and the injured, generate hypotheses, and establish the time and cause of death, among other factors. To this end, Noor and Nubli (2017) developed a system known as iDepis. This system is a type of decision support system that employs a variety of statistical analyses and algorithms to determine the location and cause of death. This highly reliable system guides forensic experts in managing decomposing bodies (Noor and Nubli 2017). While in the current study, the system determines the amount of physical damage based on clinical examinations and the compensation and wergild. Nevertheless, the results of evaluating the accuracy of both systems were satisfactory.

Costantini et al. (2019) conducted a study titled "Research on Digital Forensics and Artificial Intelligence." This study aimed to develop hypotheses that can be used as courtroom evidence. According to the findings of this study, artificial intelligence can be used to evaluate evidence and make appropriate decisions (Costantini et al. 2019). Consequently, the cited research differs from the present one in terms of its objective and methodology, but its evaluation results are entirely consistent with ours.

The results of the present study indicated that the documentation quality increased from 78.2 to 100%. A review of studies revealed that in 64% of papers, completeness was the most frequently assessed aspect of data quality (Sugiarti 2020). The potential benefits of an intelligent system in healthcare documentation include enhanced documentation quality, increased communication between users, reduced paperwork, and provided cost savings. Electronic records permit real-time access, which expedites data searches and boosts physician productivity (Jedwab et al. 2019).

Most studies that have designed decision support systems for forensic medicine have employed machine learning algorithms (Yeow et al. 2014; Shen et al. 2006; Oatley et al. 2006), whereas the system developed in this study uses a rule-based approach according to the nature of the process. Our investigation employs knowledge-based methods as opposed to machine learning algorithms. In comparison to machine learning methods, the results of some studies indicate a high degree of accuracy (approximately 100%) (Hyung et al. 2020). The current research suggests that the knowledge scope should be available to developers in evidence-based diagnosis. This is because knowledge-based methods result in transparency and a design that stakeholders more easily understand.

The inference process of several machine learning algorithms, such as artificial neural networks, is vague to expert interpretation, whereas the knowledge-based algorithm behaves like a white box. Analyzing the path to solving a problem in numerous forensic challenges is essential. Due to the unpredictability of forensic medicine, knowledge-based methods assist in examining the relationships between rules and outcomes (Khanam et al. 2019).

As a result of the system's extremely high accuracy, the use of this system improves compliance with instructions. This increase occurs because the system simplifies instructions and calculations, reducing complexity (Goud et al. 2010). This result was comparable to similar research (Karlsson 1998; Mapes et al. 2019).

To the extent that information systems, such as decision support systems, have permeated the forensic medicine system, they have not been as effective. Usability issues with these systems account for most of these inefficiencies. Usability has a substantial effect on the acceptance and intended application of systems. Without this capability, users cannot obtain the system's features and functions' potential benefits. Usability is, therefore, crucial for the successful application and use of these systems. However, in the majority of this research's studies, this important factor was overlooked when evaluating the systems, whereas the results of this study indicate that the designed system has the highest score at this point of evaluation.

Due to their busy schedules and time constraints, coordinating meeting times with forensic doctors to extract and approve decision rules and evaluate and approve the system was the most significant limitation of this study. The research team best managed this limitation by utilizing remote communication infrastructure and careful planning.

Conclusions

This study successfully developed and evaluated a decision support system for determining the amount of wergild and compensation based on forensic medicine clinical examinations and the severity of the patient's injury. The system incorporated a comprehensive set of 264 data elements and utilized intelligent decision-making algorithms, resulting in 100% accuracy, sensitivity, and specificity. With improved documentation quality and high usability scores, the system proved to be effective in quantifying physical damage and empowering forensic medicine physicians. The implementation of this system in forensic medicine's administrative and clinical processes holds significant potential for improving decision-making accuracy and reducing errors. Furthermore, considering the system's robust performance and the demand for such solutions in the market, its production and commercialization can lead to successful market penetration. Ultimately, the adoption of this decision support system has the potential to enhance the efficiency, clarity, and accuracy of law and justice proceedings, bringing about positive societal impact. Further research and development can explore opportunities for enhancing the system's functionalities, expanding its application domains, and ensuring its compatibility with existing forensic medicine frameworks. By continually refining and advancing decision support technologies in this field, we can strive for better outcomes, increased fairness, and enhanced outcomes for individuals and society as a whole.

Abbreviations

MVC	Model-view-controller
DB	Database
SQL	Structured query language
HTML	HyperText Markup Language
CSS	Cascading style sheets
SUS	System Usability Scale
TP	True positive
TN	True negative
FP	False positive
FN	False negative
RBR	Rule-based reasoning

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Authors' contributions
BS and TSS conceived the original idea. SHC designed the study. ATM collected data. ATM and SHC analyzed and interpreted the data. ATM and PRH prepared the first manuscript draft. All authors contributed significantly and critically to the final manuscript.

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Availability of data and materials
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Declarations

Ethics approval and consent to participate
This article does not contain any studies with human participants or animals performed by any of the authors. The Ethics Committee of Tabriz University of Medical Sciences has confirmed this research (IR.TBZMED.REC.1400.875).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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