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Original Article

Value of internet of things-based diagnosis-treatment model in improving the quality of medical services during COVID-19 outbreak

Chenyu Wang, Xi Chen, Xueping Zhao, Xiantao Huang, Limin Pan

The First Affiliated Hospital of Hebei North University, Zhangjiakou 075000, Hebei, China

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Abstract: Objective: To demonstrate the value of Internet of things (IoT)-based diagnosis-treatment model in improving medical service quality during the novel coronavirus pneumonia (COVID-19) outbreak. Methods: In this retrospective analysis, 483 patients with chronic diseases treated between January 2020 and March 2021 were selected and grouped as follows based on different intervention methods: a research group (the Res group) with 229 patients that were given IoT-based diagnosis and treatment, and a control group (the Con group) with 254 patients that were treated with routine diagnosis and treatment. The qualified rate of medical records, the missing rate of medical records, and the incidence of doctor-patient disputes were compared between the two groups. In addition, investigations were made regarding patients' daily living ability, psychological state, health behavior, self-care ability, quality of life, as well as treatment satisfaction. Results: There was no difference in the qualified rate of medical records between the Res group and the Con group ($P>0.05$), but the missing rate of medical records and the incidence of doctor-patient disputes were lower in the Res group (both $P<0.05$). An obviously improved living ability was observed in both groups after the treatment (both $P<0.05$), with no statistical significance between groups ($P>0.05$). Besides, the Res group presented lower scores of SAS and SDS but higher scores of SRAHP, ES-CA and SF-36 than the Con group after treatment (all $P<0.05$). Finally, according to the satisfaction survey, more patients in the Res group were very satisfied but fewer cases were dissatisfied with the medical service they received as compared with the Con group (both $P<0.05$). Conclusions: The IoT-based diagnosis-treatment model can effectively improve the quality of medical services and patients' self-care ability, which is extremely important and promising for addressing the current medical limitations during the COVID-19 epidemic.

Keywords: Internet of things-based diagnosis and treatment, medical service quality, living ability, self-care ability, degree of satisfaction

Introduction

Novel coronavirus pneumonia (COVID-19) is a global pandemic infectious disease that broke out in 2019, with the first outbreak in China reported in Wuhan [1]. Even today, the COVID-19 infection has not been effectively controlled, and the daily increases of infected patients is still not optimistic on a global scale [2]. As of December 10, 2021, a total of 267,865,289 cases of COVID-19 infections have been confirmed worldwide, including 5,285,888 deaths. COVID-19 has a higher infection rate and longer duration than the SARS outbreak in 2008 [3]. After two years of intensive research in various countries around the world, COVID-19 vaccines have been developed preliminarily, but there are still countless infected people even after vaccination [4]. Recently, B.1.1.529 Omicron, a variant strain of COVID-19 with higher infection and fatality rates, has been found in South Africa and other countries [5]. As COVID-19 can spread through respiratory tract, digestive tract, contacts, insect vectors, blood, body fluids and other ways, countries all over the world have adopted mandatory home isolation and travel restriction measures to control infection rate by reducing crowd aggregation [6]. Although this has reduced the risk of COVID-19 infection to certain extent, it has caused great trouble to the social life of people.

Hospitals are indispensable places in the social life of mankind. Social isolation has enormously affected the normal medical needs of the masses. For some sudden diseases, it has caused many inconveniences and even death of some patients with critical diseases since they can't get medical treatment in time [7, 8]. On the other hand, in the face of the COVID-19, medical staff are required to carry out additional prevention and testing procedures, which increase the workload and pressure of medical staff [9]. During the outbreak of COVID-19, many medical workers have died from infections, overwork and other causes [10].

Therefore, in the face of COVID-19, how to effectively implement the home quarantine advocated by the country while improving the quality of patients' medical treatment has become a hot spot in clinical research. Our hospital immediately launched a multi-mode telemedicine network since the first outbreak of the epidemic in 2019; this network cooperates with newly established 5G services, smart phone applications and existing telemedicine systems to realize the combination of online and offline services, and provide basic medical support to the public through real-time telemedicine consultation, online psychological consultation, regular follow-up and online guidance to reduce the number of patients entering the hospital, thus preventing potential cross-infection while reducing medical expenses for individuals [11, 12]. At present, the application of the Internet of things (IoT)-based diagnosis-treatment model has achieved remarkable results in our hospital and are hereby reported to provide more scientific, reasonable and effective suggestions and opinions for the follow-up medical care during the COVID-19 epidemic.

Materials and methods

Research participants

In this retrospective research, we incorporated 483 patients with chronic diseases who were treated at the First Affiliated Hospital of Hebei North University between January 2020 and March 2021. Patients were allowed to choose either the IoT-based diagnosis-treatment model or the routine diagnosis and treatment after initial admission, with 229 patients included in the research group (the Res group) for the IoT-based model and 254 cases included in the control group (the Con group) for the routine model. This experiment strictly abided by the *Declaration of Helsinki*. The study was approved by the First Affiliated Hospital of Hebei North University Ethics Committee.

Criteria for patient enrollment and exclusion

All the eligible patients (>18 years old) were diagnosed with chronic diseases (e.g., hypertension, diabetes, and coronary heart disease) after examination in the First Affiliated Hospital of Hebei North University with a course of disease >1 year and a certain degree of Internet treatment and application basis. In addition, all patients volunteered to participate in this study, with complete case data and no psychiatric disorders or history of mental illness.

Cases were excluded based on the following criteria: (1) with the need of long-term hospitalization; (2) with other critical diseases, infectious diseases, tumors or organ failure; (3) with disease exacerbation during the treatment; (4) in pregnancy and lactation; (5) with inability to complete the investigation due to hospital transfer during treatment and follow-up.

Methods

Patients in the Con group were treated with routine diagnosis and treatment. After admission, they were treated according to routine procedures such as registration, waiting, consultation, etc., and the process of returning to hospital for reexamination was the same as above.

The Res group adopted the IoT-based diagnosis-treatment model. An IoT-based diagnosis-treatment platform was constructed based on the Wechat Mini program, including an online consultation module, a medical treatment guidance module, and a science service module. The details are as follows: (1) Collecting and sorting out the patient's case data through the Internet cloud: patients were asked to fill in their information in detail and upload it at the first admission for clinicians to review at any time, so as to realize the sharing, utilization and evaluation of patients' health information by relevant medical staff, patients or main caregivers at all levels. (2) Opening convenient network channels such as remote registration and consultation: through these channels, patients were allowed to quickly complete treatment preparation and basic consultation through mobile phones and computers without leaving their homes. (3) Setting up a doctor-patient communication group: medical staff were arranged to answer patients' questions and doubts in time on this communication platform, and provide disease-related health knowledge daily. (4) Formulating reexamination plans: the corresponding regular reexamination arrangement was developed based on each patient's specific condition and was communicated through the WeChat platform to remind the patient of timely reexamination.

Evaluation criteria

This time, we mainly started from the aspects of patient management, living ability, psychological state, behavior score and self-care ability, quality of life, and treatment satisfaction, etc., and evaluated the impact of the implementation of the Internet medical diagnosis and treatment model on the quality of medical services during the new coronary pneumonia period through comprehensive analysis.

Patient management: the qualified rate of medical records of all admitted patients (qualified if the case records were complete without omission), the missing rate of medical records (loss of medical records), and the incidence of doctor-patient disputes during treatment were recorded. Assessment of daily living ability: it was assessed with the Activities of Daily Living (ADL; score range: 14-56) Scale from two items, with a score of 14, 15-20, >15-20 indicating normal, light dependence, and severe dependence in daily living, respectively. Psychological state assessment: the Self-rating Depression Scale (SDS) and Self-rating Anxiety Scale (SAS) were used for evaluation, and the standard score was calculated as the total score × 1.25, with higher scores indicating worse psychological states. Health behavior score: it was evaluated by the Self-Rated Abilities for Health Practices (SRAHP) scale from six items, with higher scores indicating greater abilities for health practices. Self-care ability: the Exercise of Self-care Agency (ESCA) scale, including four items, was used for evaluation; higher scores indicated greater self-care ability. Quality of life assessment: the Short-Form 36 Item Health Survey (SF-36) was adopted; the scale has 8 dimensions, with higher scores representing a better quality of life. The above assessments were performed at the time of initial admission and 6 months after treatment. Treatment satisfaction: after 6 months of treatment, an anonymous satisfaction survey was conducted by using the self-made satisfaction scale of our hospital; the full score was 10, with a score below 5 as dissatisfied, 5-7 as improvement needed, 8-9 as basically satisfied, and 10 as very satisfied.

Statistical methods

Statistical analysis was performed using SPSS22.0. The Chi-square test was used to identify inter-group differences of count data recorded as [n (%)]. For measurement data represented by χ ± sd, the comparison was made by the independent sample t test. When P< 0.05, the difference between groups was statistically significant.

Results

Comparison of clinical baseline data

First of all, in order to ensure the credibility of the experimental results, we compared the age, sex, basic disease types and other baseline data and found no statistical difference between the Res and the Con groups (P>0.05), indicating that the two groups were comparable (**Table 1**).

Comparison of patient management

According to statistics, there was no significant difference in the qualified rate of medical records between the two groups (P>0.05), but the missing rate of medical records and the incidence of doctor-patient disputes were lower in the Res group compared with those in the Con group (P<0.05), as shown in **Table 2**.

Comparison of living ability

The ADL assessment showed no difference in daily living ability between the Res group and the Con group at the time of initial admission and after treatment (P>0.05). In both groups, the number of patients with normal living ability after treatment increased significantly compared with that at the initial admission, while the number of patients with severe dependence decreased significantly (all P<0.05; **Table 3**).

Table 1. Comparison of clinical baseline data ($\overline{X}$ ± sd)/[n (%)]

		Research group	Control group	t/χ^2	P
Age (years)		54.63±8.74	55.14±10.12	0.590	0.556
Course of disease (years)		2.04±0.62	1.97±0.53	1.337	0.182
Disease types	Diabetes mellitus	86 (37.55)	90 (35.43)	0.732	0.694
	Hypertension	94 (41.05)	114 (44.88)		
	Coronary heart disease	49 (21.40)	50 (19.69)		
Sex	Male	139 (60.70)	146 (57.48)	0.516	0.473
	Female	90 (39.30)	108 (42.52)		
Residence	Urban areas	162 (70.74)	193 (75.98)	1.699	0.192
	Rural areas	67 (29.26)	61 (24.02)		
Ethnicity	Han	214 (93.45)	242 (95.28)	0.761	0.383
	Ethnic minorities	15 (6.55)	12 (4.72)		
Smoking	Yes	98 (42.79)	104 (40.94)	0.169	0.681
	No	131 (57.21)	150 (59.06)		
Drinking	Yes	64 (27.95)	75 (29.53)	0.147	0.702
	No	165 (72.05)	179 (70.47)		
Family medical history	With	82 (35.81)	95 (37.40)	0.132	0.717
	Without	147 (64.19)	159 (62.60)		

Table 2. Comparison of patients' medical records management [n (%)]

	Qualified rate of medical records	Missing rate of medical records	Doctor-patient disputes
Research group	220 (96.07)	15 (6.55)	3 (1.31)
Control group	242 (95.28)	36 (14.17)	12 (4.72)
χ^2	0.183	7.410	4.666
P	0.669	0.007	0.031

Comparison of psychological states

The psychological state evaluation revealed no marked difference in SAS and SDS scores between the Res group and the Con group at the initial admission (both P>0.05). The scores of the Con group did not change significantly after treatment (P>0.05), but those of the Res group reduced markedly and were lower versus Con group (all P<0.05; **Table 4**).

Comparison of behavior score and self-care ability

The SRAHP score differed insignificantly between groups at the initial admission (P>0.05), while an increase was found in the score of each item after treatment. The Res group exhibited similar pressure regulation, responsible health practices and interpersonal relationship scores than the Con group (P>0.05), but higher scores in psychological wellbeing, nutrition and exercise (P<0.05; **Table 5**).

Comparison of self-care ability

The two groups had no significant difference in the ESCA score at the initial admission (P>0.05). After treatment, the ESCA score of both groups increased and was higher in the Res group than that in the Con group (P<0.05; **Table 6**).

Comparison of quality of life

The SF-36 score was similar in the two groups at the initial admission (P>0.05); an elevation was observed in the SF-36 score after treatment, with an obviously higher score in Res group versus the Con group (P<0.05; **Table 7**).

Comparison of treatment satisfaction

Finally, according to the satisfaction survey results, the number of people who rated the service as improvement needed did not differ between the two groups (P>0.05), while the number of people who were very satisfied was significantly higher in the Res group and the number of patients who were dissatisfied with the medical service was significantly lower (P< 0.05; **Table 8**).

Table 3. Comparison of living ability [n (%)]

	At the initial admission			After treatment		
	Normal	Mild dependence	Severe dependence	Normal	Mild dependence	Severe dependence
Research group	43 (18.78)	118 (51.53)	68 (29.69)	94 (41.05)*	114 (49.78)	21 (9.17)*
Control group	51 (20.08)	122 (48.03)	81 (31.89)	99 (38.98)*	128 (50.39)	27 (10.63)*
χ^2	0.130	0.589	0.272	0.215	0.018	0.287
P	0.718	0.443	0.602	0.643	0.893	0.592

Note: *indicates that there is a difference compared with the score at the time of initial admission within the group (P<0.05).

Table 4. Comparison of psychological states ($\overline{X}$ ± sd)

	At the initial admission		After treatment	
	SAS score	SDS score	SAS score	SDS score
Research group	54.63±6.42	57.24±5.63	32.15±10.54*	35.63±8.70*
Control group	55.14±7.06	56.84±6.71	54.14±5.67	55.34±8.13
t	0.827	0.706	28.930	25.730
P	0.408	0.481	<0.001	<0.001

Note: *indicates that there is a difference compared with the score at the time of initial admission within the group (P<0.05). SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale.

Discussion

With the ongoing COVID-19 pandemic, healthcare systems all over the world are being put to the test. When addressing this challenge, the limitations of traditional medical systems in disaster preparedness and prevention have not only increased the work intensity and stress of health care workers, but also resulted in the lack of satisfactory treatment services for patients and increased risk of infections [13, 14]. With the use of new scientific technologies such as 5G big data analysis, cloud computing and artificial intelligence, a new diagnosis and treatment model - IoT-based medical treatment is rapidly emerging [15]. The growth of Internet access speed and the improvement of its performance brought about by the new technology have made the Internet the focus of many new medical developments, especially in the field of telemedicine and the communication between patients and medical professionals, significantly transforming medical outcomes and providing lessons for the rest of the world [16]. However, as a new thing, it comes with some certain risks. How to ensure the quality of IoT-based healthcare and properly evaluate the risks and benefits have become important issues.

In this study, we first analyzed the case management under the IoT-based diagnosis-treatment model. The results showed no difference in the qualified rate of medical records between the Con and the Res groups, indicating that the IoT-based model can also effectively collect the patient's case information as the conventional diagnosis and treatment. Besides, the reduction of the missing rate of medical records in the Res group demonstrates that IoT-based diagnosis and treatment is more conducive to preserving patients' case records, which is consistent with the findings of the study by Termoz et al. on the integration of Internet platforms with medical record management [17]. We believe that relying on the current cloud storage technology, we can quickly summarize and save patients' case information and review the records just by clicking the saved case again when necessary. And compared with the traditional paper medical records, the information saved through the Internet is less likely to be lost and forgotten, which greatly improves the work efficiency of medical staff. The report of Fanghua et al. on elderly patients with hypertension also suggested the efficiency improvement of Internet-based medical diagnosis and treatment model [18]. Moreover, we found that the incidence of doctor-patient disputes was evidently lower in the Rest group versus the Con group, which is an affirmation of the application effect of the IoT-based diagnosis-treatment model. Doctor-patient disputes have long been a key issue of great concern. The occur-

Table 5. Comparison of health behavior scores ($\overline{X}$ ± sd)

	At the initial admission						After treatment					
	Pressure regulation	Psychological wellbeing	Nutrition	Interpersonal relationship	Exercise	Responsible health practices	Pressure regulation	Psychological wellbeing	Nutrition	Interpersonal relationship	Exercise	Responsible health practices
Research group	1.14±0.84	1.24±0.54	1.84±1.04	2.24±0.54	1.72±0.74	2.42±0.36	3.62±0.54	4.12±0.42	4.42±0.26	3.48±0.46	3.34±0.26	3.84±0.52
Control group	1.21±1.02	1.30±0.67	1.79±1.15	2.17±0.63	1.79±0.89	2.47±0.42	3.53±0.81*	3.23±0.73*	2.98±1.24*	3.39±0.69*	2.86±0.35*	3.71±0.63*
t	0.818	1.076	0.499	1.340	0.934	1.397	1.421	16.190	17.230	1.668	16.960	2.458
P	0.414	0.282	0.618	0.193	0.351	0.163	0.156	<0.001	<0.001	0.096	<0.001	0.014

Note: *indicates that there is a difference compared with the score at the time of initial admission within the group (P<0.05).

Table 6. Comparison of self-care ability ($\overline{X}$ ± sd)

	At the initial admission				After treatment			
	Health knowledge	Self-care concept	Self-care skills	Self-care responsibility	Health knowledge	Self-care concept	Self-care skills	Self-care responsibility
Research group	1.72±0.24	2.17±0.18	1.84±0.84	2.06±0.45	4.52±0.34*	3.68±0.74*	4.06±0.62*	4.34±0.26*
Control group	1.75±0.32	2.20±0.24	1.82±0.73	2.11±0.53	3.15±0.84*	3.04±0.39*	3.24±1.05*	3.18±1.14*
t	1.156	1.541	0.280	1.111	23.040	12.050	10.310	15.050
P	0.248	0.124	0.780	0.267	<0.001	<0.001	<0.001	<0.001

Note: *indicates that there is a difference compared with the score at the time of initial admission within the group (P<0.05).

Table 7. Comparison of quality of life ($\overline{X}$ ± sd)

	At the initial admission	After treatment
Research group	62.81±10.14	82.06±9.70*
Control group	63.70±8.94	76.63±10.14*
t	0.306	5.998
P	1.025	<0.001

Note: *indicates that there is a difference compared with the score at the time of initial admission within the group (P<0.05).

Table 8. Comparison of treatment satisfaction [n (%)]

	Very satisfied	Basically satisfied	Improvement needed	Dissatisfied
Research group	127	54	34	14
Control group	76	101	42	35
χ^2	32.230	14.470	0.259	7.764
P	<0.001	<0.001	0.611	0.005

rence of doctor-patient disputes not only reduces the enthusiasm of medical staff, but may also adversely affect the rehabilitation of patients [19]. The application of the IoT-based diagnosis-treatment model can quickly and clearly guide patients to complete the admission and treatment process through artificial intelligence and respond to related questions raised by patients in real time, thus greatly improving the convenience of treatment and recognition of patients [20]. Subsequently, in various surveys of patients, we found that the daily living ability of both groups were significantly improved after treatment, with no evident inter-group differences, which indicates that the IoT-based diagnosis-treatment model can also achieve the ideal rehabilitation treatment effect. On the other hand, the inter-group comparison of the psychological state revealed more significantly reduced scores of SDS and SAS in the Res group after treatment, suggesting that IoT-based diagnosis and treatment can also improve the psychological state of patients. At present, the services provided by the IoT-based diagnosis-treatment model mainly include consultation, appointment registration, disease management and online pharmacy. With the development of 5G networks and WIFI technology, and the popularity of mobile phones and other hardware facilities, this model enables patients to make appointments for specialist clinics through WeChat official accounts and APPs without leaving their homes, increasing access to medical care and reducing on-site waiting time. Moreover, online remote consultations can also provide a more convenient way for patients who are not convenient to see a doctor on the spot, which greatly solves the problems faced by patients with medical conditions and improves their treatment experience. Further, the evaluation results of behavior score and self-care ability identified better improvements in the Res after treatment, which further demonstrates the promising application potential of the IoT-based diagnosis-treatment model. At this stage, the IoT-based diagnosis and treatment is a novel medical service model for patients with chronic diseases (diabetes, hypertension etc.) that usually come along with a very long course of disease and treatment cycle [21]. As the basis of many critical and complicated diseases, diabetes and hypertension need to be strictly controlled for disease stabilization in daily life, and any behaviors that may induce disease outbreaks should be avoided as much as possible [22], which is a great challenge for patients who lack medical and health knowledge. While IoT-based diagnosis and treatment can record a patient's physical condition in real time through the establishment of a cloud electronic archive. Meanwhile, medical staff can easily and quickly understand the patient's prognosis through the follow-up platform, and conduct timely troubleshooting and guidance [23, 24]. This process not only imperceptibly enhances patients' disease awareness and related self-care knowledge, but also makes them feel valued, thus improving their trust and dependence on medical staff, which has important implications for the management of chronic diseases requiring long-term treatment. Finally, the improvement of patients' quality of life and the affirmation of the service as reflected in high treatment satisfaction after treatment further emphasize the application reliability of the IoT-based diagnosis-treatment model. Overall, the results of this experiment suggest that IoT-based diagnosis and treatment may have an extremely important application prospect in any future medical scenarios rather than COVID-19 alone.

We believe that in the face of the current COVID-19 pandemic which may last for a long time, medical service institutions need to constantly establish new communication channels and adapt to new participation systems. The emergence of the IoT-based diagnosis-treatment model just effectively validates our viewpoint. This novel model helps medical service institutions to strengthen contacts with patients, enabling the provision of preventive treatment and personalized services [25]. It can also assist hospitals in delivering more effective information to patients and help patients establish good medication or postoperative rehabilitation habits. Furthermore, it enables patients who see a doctor at a prefecture-level hospital to have more opportunities to be consulted by experts from local hospitals and top hospital specialists. Moreover, with remote, real-time guidance by doctors from well-known hospitals, the technical level of medical staff in local hospitals can be improved, thus narrowing the gap between local hospitals and top hospitals.

Conclusion

The IoT-based diagnosis-treatment model can effectively improve the quality of medical services and patients' self-care ability, which has important significance and promising application prospects for addressing the current medical limitations during the COVID-19 pandemic and beyond.

Disclosure of conflict of interest

None.

Address correspondence to: Chenyu Wang, The First Affiliated Hospital of Hebei North University, Zhangjiakou 075000, Hebei, China. Tel: +86-0313-8043722; E-mail: wangchenyu1987@yeah.net

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