Experimental Study on Evaluation of Blood Supply Level and Embolization Ratio of Liver Cancer Based on I-Flow Software

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Abstract

Objective: To confirm the feasibility and accuracy of the method for evaluating blood supply and embolization rate of liver cancer based on I-flow software through animal experiments and clinical study. **Methods:** Rabbits underwent selective angiography under different perfusion conditions in the same kidney. The blood supply level was evaluated by I-flow software method. The results were analyzed for coefficient of variation. Thirty patients with liver cancer who underwent selective hepatic artery embolization were enrolled. The mathematical methods and 3 diagnostic specialists were used to evaluate the preoperative blood supply level and embolization rate. The results were recorded and the results were tested for consistency. **Results:** Animal experiments confirmed that the blood supply level analysis method designed by the research team was consistent under different contrast conditions (including total contrast agent, contrast medium perfusion rate, and limiting pressure) (coefficient of variation: 8.55%). The mathematical calculation results of preoperative blood supply level and embolization ratio of liver cancer are consistent with the average value of visual judgment results of diagnostic experts. (Preoperative blood supply level: concordance coefficient = 0.284, P = 0.003; embolization ratio: concordance coefficient = 0.218, P = 0.011). **Conclusion:** Based on I-flow software, the mathematical calculation method designed by this research group can effectively estimate the preoperative blood supply level of liver cancer and the embolization rate of single vascular embolization treatment, which can provide reliable data support for embolization treatment of liver cancer.

Liver cancer is a common malignant tumor, which is more common in Asia and the incidence rate is 1 in 10000. Nearly half of the annual primary liver cancers in the world occur in China. Its mortality rate is second only to gastric cancer and lung cancer.[1,2] Liver cancer is one of the common malignant tumors that seriously endanger human health. It is known for its highly malignant characteristics and has a very poor prognosis.[3] In the current treatment methods, surgical resection is the preferred method for liver cancer, but because the early symptoms are not obvious. Once found, most of them have reached the middle and late stage, and 80% of them are not suitable for surgical resection.[3,4] In the past 20 years, minimally invasive interventional therapy has been widely used. Transcatheter arterial embolization has been widely recognized

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in the medical community. The 1-, 3-, and 5-year survivals were 82%, 47% and 26%, respectively,[5] and were recognized as the preferred treatment for unresectable liver cancer.[6,7] 70% of patients in the United States who are awaiting liver transplantation receive this treatment.[8]

Many patients with liver cancer in the clinic cannot complete the tumor embolization at one time due to the large tumor volume or liver dysfunction. It is often necessary to gradually embolize the tumor in multiple times to achieve the desired embolization effect.[9] It is generally believed that the tumor blood supply of primary liver cancer is a key factor affecting the therapeutic effect of selective arterial embolization. The richer the blood supply to the tumor, the more favorable it is for the filling and deposition of embolic drugs. On the contrary, the total amount of filling of the agent is insufficient to produce sufficient killing effect on the tumor with less blood supply. In addition, according to the blood supply level of the tumor, it is also very important to develop a more accurate individual embolic dose before operation.[10] If the dose is too high, the liver function damage will be aggravated, and if it is too low, the effect will be poor.[11,12] Although the determination of the embolic dose is influenced by a number of factors, the blood supply to the tumor is considered to be an important determinant.

However, currently, there was no direct use of imaging or clinical tools to quantify tumor blood supply and embolization ratios, usually relying on empirical estimates and subjective analysis by clinicians. Due to the large differences in subjective factors, the results of treatment evaluations obtained by different medical units and even different doctors are not comparable. Non-quantitative evaluation results limit the standardization and sustainability of patient clinical treatment. Therefore, this study hopes to establish a new and effective quantitative evaluation method to objectively and comparatively evaluate the degree of single embolization therapy, thereby minimizing the dependence on the doctor's experience and subjective judgment. This method can improve the standardization and datamation of clinical treatment, help to formulate more effective and accurate treatment plans, reduce the uncertainty caused by human estimation, and thus improve the benefit of patients' treatment.

The I-flow software provided by the Siemens digital subtraction angiography (DSA) workstation is capable of measuring the contrast enhancement in a given area and can be of great help for clinical calculations.[13] However, the results of contrast enhancement cannot be directly applied because the total amount of contrast agents, contrast agent speed, and limiting pressure vary widely. Such a difference makes the contrast agent concentration results incomparable. Based on the above problems, the research team designed a mathematical method for evaluating the blood supply of solid tumors based on the calculation function of I-flow software, and verified that the mathematical method has high accuracy and clinical practical value through animal experiments and preliminary clinical experiments.

Experimental Methods and Materials

Mathematical Method Design

According to the clinical practice, the research team designed a mathematical method for evaluation of blood supply of solid tumors.

The starting area of the artery at the opening of the angiography catheter (usually the starting portion of the hepatic artery) is used as the reference region (ref), the tumor region is the target region (tar), and the normal liver parenchyma region adjacent to the tumor is the standard region (sta) . An example of the use of this mathematical method is shown in Figure 1.

Tumor blood supply (G). I-flow software was used to separately describe the enhancement curve of the reference region (ref), target region (tar) and standard region (sta) in one contrast medium contrast sequence, and calculate the area under the curve of each enhancement curve separately (AUC). Divide the AUC of each region by the area value of the regions to obtain the enhancement value per unit area. The unit area enhancement values of the target region and the standard region were compared with the unit area enhancement of the reference region, respectively. The standard region ratio was subtracted from the target region ratio to obtain the average blood supply level (G) of the target region.

$$\begin{cases} AUC = \sum_{i=1}^{n-1}(X_{i+1}-X_i)\min(Y_i,Y_{i+1})+(1/2)(X_{i+1}-X_i)|Y_{i+1}-Y_i| \\ G = \dfrac{AUC_{tar}}{AUC_{ref}} \times \dfrac{S_{ref}}{S_{tar}} - \dfrac{AUC_{sta}}{AUC_{ref}} \times \dfrac{S_{ref}}{S_{sta}} \end{cases}$$

AUC_{tar}: Area under the enhancement curve of the target region

AUC_{sta}: Area under the enhancement curve of the standard region

AUC_{ref}: Area under the enhancement curve of the reference region

S_{tar}: Area of the target region

S_{sta}: Area of the standard region

S_{ref}: Area of the reference region

Embolization ratio. We use the above methods to measure the blood supply of the tumor before and after embolization. The blood supply level value obtained by angiography after embolization in the target region (G_{post}) was subtracted from the blood supply level value obtained by angiography before embolization (G_{pre}). The difference value obtained was compared with the value of the contrast blood supply level before embolization, so as to obtain the proportion of the blood supply reduction after embolization.

$$\text{Embolization ratio}(\%) = \frac{G_{pre}-G_{post}}{G_{pre}} \times 100\%$$
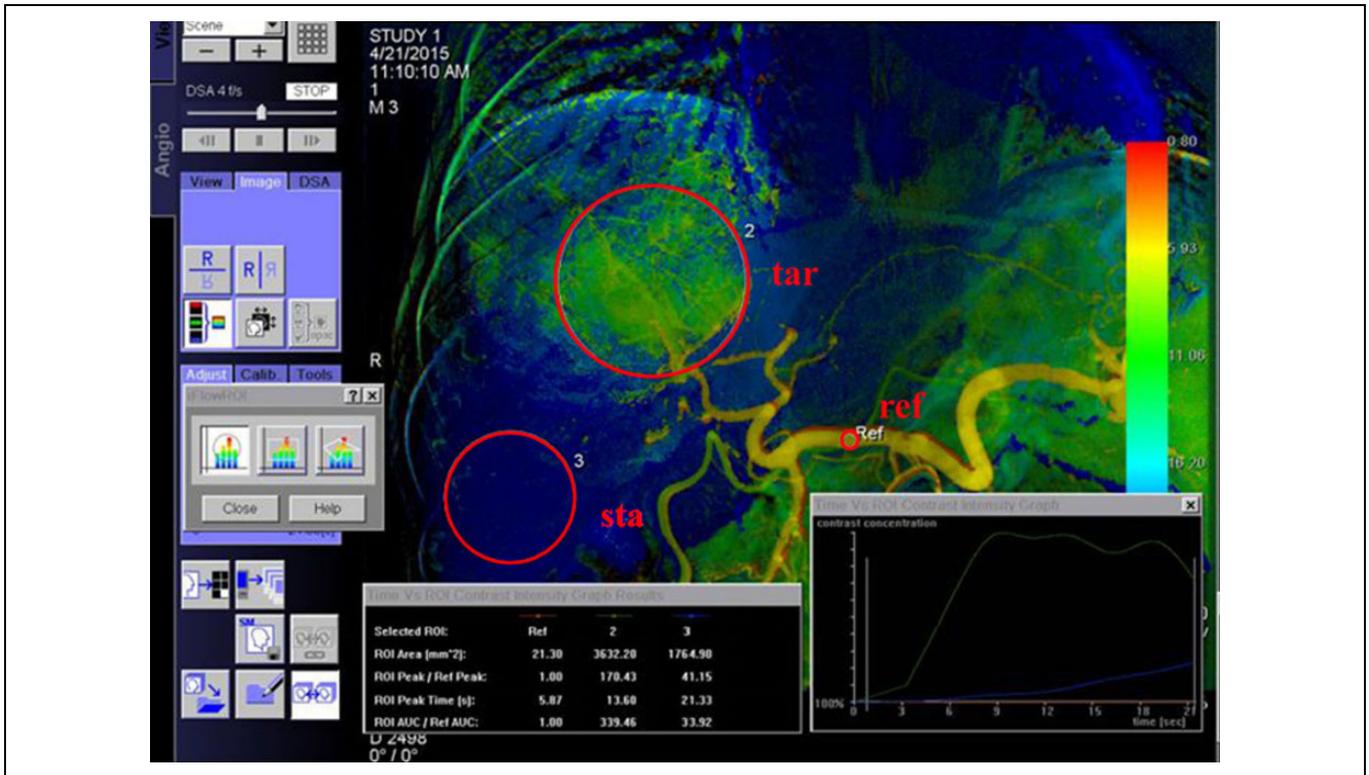
Figure 1. The demonstration for the assessment of blood perfusion at indicated region by mathematical method.

G_{pre}: Preoperative tumor blood supply
G_{post}: Postoperative tumor blood supply

Animal Experiments

In order to avoid individual differences, we chose the same New Zealand white rabbit, under the condition of monitoring and maintaining various vital signs of the white rabbit, different conditions were used for perfusion with sufficient time interval. Single kidney of the rabbit was selected as the perfusion region, and different total perfusion volume, perfusion rate, and limiting pressure conditions were used for selective renal angiography. The area under the curve of the enhancement degree of the target region under different contrast conditions and the blood supply evaluation result of the tumor after mathematical treatment were recorded separately.

Patients Enrolled

This study was approved by the Ethics Committee of Tianjin Medical University, registration code E2018295, and was conducted at the Cancer Hospital of Tianjin Medical University from January 2018 to December 2019.

(1) Inclusion criteria:
   1) Patients with BCLC stage IIb, IIIa and some stage IIIb liver cancer;
   2) Liver function: Child-Pugh A or B;
   3) PS score 0-2 points;

(2) Exclusion criteria:
   1) Severe dysfunction of liver function (Child-Pugh C);
   2) Uncorrectable coagulation dysfunction;
   3) The main portal vein is completely embolized by cancer, and the formation of collateral vessels is less;
   4) Those with active hepatitis or severe infection who cannot be treated simultaneously;
   5) Extensive metastasis of distant tumors, estimated survival time <3 months;
   6) Those with cachexia or multiple organ failure;
   7) The proportion of tumor to the total liver volume is ≥70%;
   8) Peripheral blood leukocytes and platelets decreased significantly, leukocytes $<3.0 \times 10^9$/ L, platelets $<50 \times 10^9$/ L;
   9) Renal dysfunction: blood creatinine> 2 mg / dl or blood creatinine clearance rate <30 ml / min.

30 patients with liver cancer who underwent selective hepatic artery embolization were enrolled in the study, including 27 male patients (90%) and 3 female patients (10%) aged 35-74 years old. The median age is 59.5 years old. There were 22 cases (73.33%) in stage B of BCLC and 8 cases (26.67%) in stage C. CHILD classification: 28 cases (93.33%) in grade A and 2 cases (6.67%) in grade B. The mathematical methods and 3 diagnostic specialists were used to evaluate the preoperative blood supply level and embolization rate, and the results were recorded.
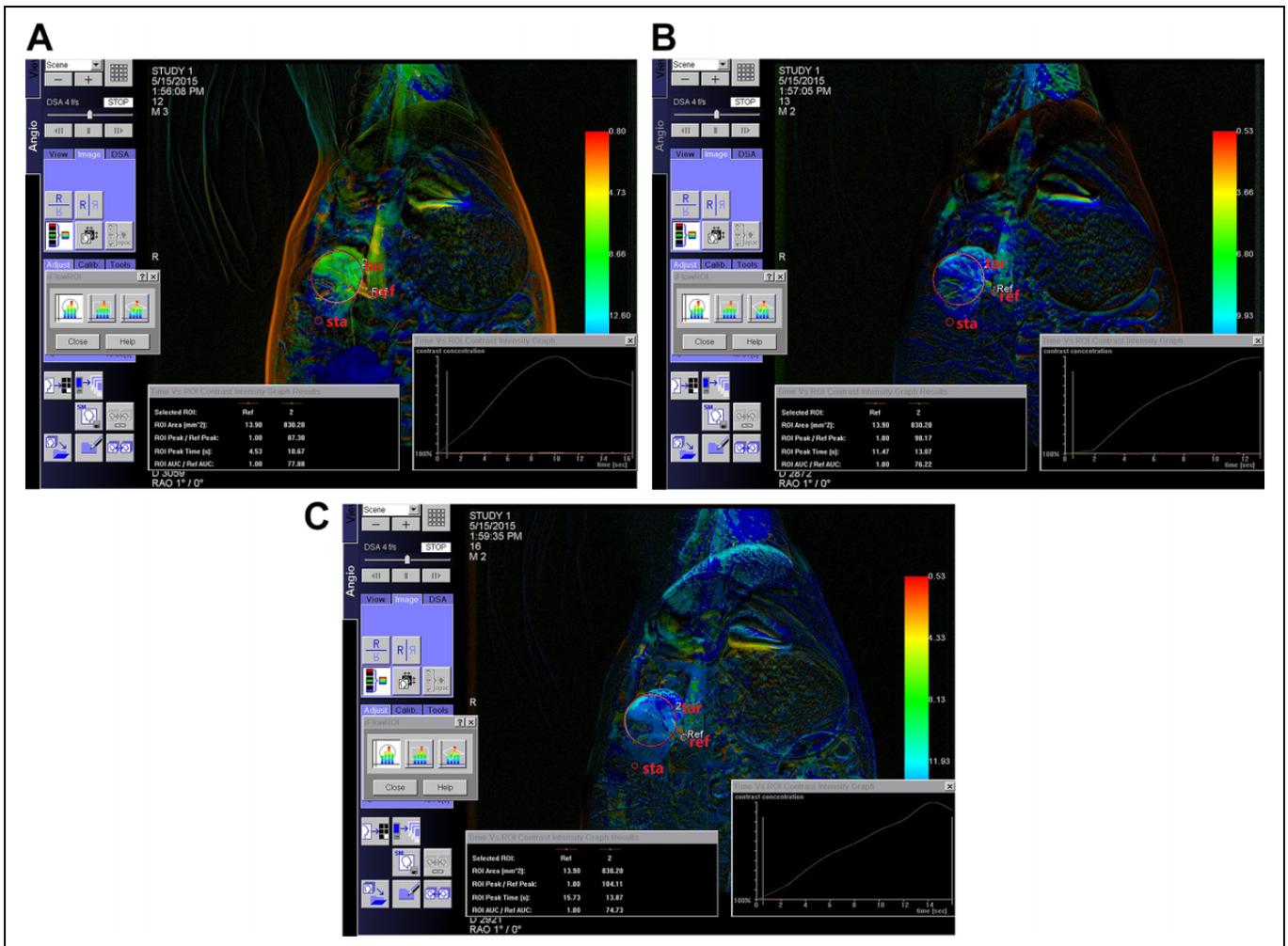
Figure 2. Contrast analysis under different perfusion conditions(ref: reference region, tar: target region, sta: standard region.

Embolization Materials and Equipment

The embolic agent uses sodium alginate microspheres. The contrast agent is iopromide. Digital subtractors and image processing workstation uses the Simens Artis zeego digital subtraction scanner and workstation. Contrast concentration analysis was performed using I-flow software, and the sequence time was analyzed from 1.33 seconds to 10.13 seconds.

Statistical Analysis

Statistical analysis was performed using SPSS 22 software and animal experiment results were tested using discrete coefficients. The consistency test of the visual results of the diagnostic experts, and the consistency test of the results of the mathematical software and the average of the visual results of the diagnostic experts, using Kendall's concordance coefficient test, when $P < 0.05$, considered consistency . The correlation test between the mathematical software measurement results and the visual results of the diagnostic experts was tested using the Spearman correlation coefficient test. When $P < 0.05$, it was considered to be relevant.

Result

Animal Experiment

The contrast catheter was selectively inserted into the beginning of the same right renal artery of the experimental animal, and the perfusion of contrast agent was analyzed under different total amount of contrast agent, contrast agent flow rate and ultimate pressure conditions, and the results were recorded. (Figure 2)

The animal experiment is based on the premise of full perfusion. The degree of enhancement obtained under different perfusion conditions and the results measured by mathematical methods are shown in Table 1.

The results of blood supply level were analyzed for coefficient of variation, which are shown in Figure 3. The results of animal experiments confirmed that the blood supply level analysis method of solid tumors used in this study group had

Table 1. Analysis Results of Tumor Blood Supply Under Different Perfusion Conditions in Same Rabbit.

Time	AUC_{tar}/AUC_{ref}	volume	Speed (ml/s)	Delay (s)	Limit pressure (KPa)	$S_{ref.}$	$S_{tar.}$	G
1	77.88	3	2	1.5	100	13.9	830.2	1.304
2	76.22	4	2	1.5	100	13.9	830.2	1.276
3	74.73	5	2	1.5	100	13.9	830.2	1.251
4	72.73	6	3	1.5	100	13.9	830.2	1.218
5	69.86	6	3	1.5	200	13.9	830.2	1.170
6	70.55	2	3	1.5	200	13.9	830.2	1.181
7	25.94	3	2	1.5	100	13.9	286.8	1.257
8	22.39	4	2	1.5	100	13.9	286.8	1.085
9	25.78	5	2	1.5	100	13.9	286.8	1.249
10	21.69	6	3	1.5	100	13.9	286.8	1.051
11	19.97	6	3	1.5	200	13.9	286.8	0.968
12	24.61	2	3	1.5	200	13.9	286.8	1.193


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Number of values        12

Minimum      0.9679
25% Percentile          1.106
Median       1.205
75% Percentile          1.256
Maximum      1.304

Mean         1.184

Std. Deviation 0.1012

Std. Error   0.02920

Lower 95% CI of mean 1.119
Upper 95% CI of mean 1.248

Coefficient of variation  8.55%

Sum 14.20
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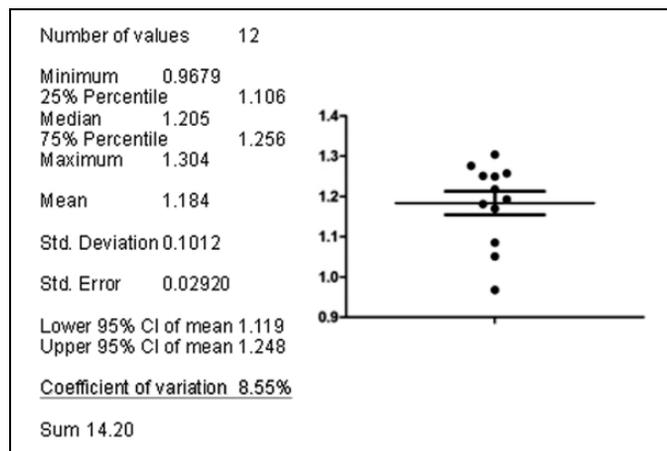
Figure 3. Analysis of coefficient of variation of blood supply level under different perfusion conditions. (coefficient of variation: 8.55%).

consistent results (Coefficient of variation: 8.55%) under different contrast conditions (including total contrast agent, contrast agent perfusion rate, and limit pressure).

Clinical Analysis

Using the mathematical analysis method designed by this research group, the imaging data of 30 patients with liver cancer treated with selective hepatic artery embolization were analyzed. The content includes preoperative tumor blood supply level and tumor embolism ratio. The results of the above analysis were compared with the diagnostic results of 3 senior diagnostic experts to verify consistency. The actual use example of the mathematical analysis method is shown in Figure 4.

Analysis of preoperative blood supply. The preoperative blood supply level results measured by software were compared with the diagnostic results of 3 high-grade imaging diagnostic experts. The results are shown in Table 2. Visual assessment of blood supply levels from 0 to 10 points from low to high.

The visual diagnostic values of the blood supply levels of liver cancer were tested by Kendall's concordance coefficient. The harmony coefficient was 0.004 and P = 0.890. The results showed that the visual values of the 3 diagnostic experts had certain differences. However, after the software measured value and the 3 experts' visual averages were tested by Kendall's harmonious coefficient, the harmony coefficient was 0.284, P = 0.003, which confirmed that the measured value was consistent with the average of the expert visual results.

The Spearman correlation coefficient analysis results show that the measured values are correlated with the evaluation results and average values of the 3 experts, and the correlation coefficient with the average results is the highest, rs = 0.918, P < 0.01, Table 3, Figure 5.

Analysis of embolization ratio. The proportion of embolization after hepatic artery embolization was quantitatively calculated by mathematical methods. The results were compared with the visual results of 3 senior diagnostic experts. The results are shown in Table 4.

The mathematical calculation results and the visual values of the 3 experts were tested by Kendall's concordance coefficient. The concordance coefficient was 0.012, P = 0.707. The results showed that the 3 diagnostic experts had some differences in the evaluation results of tumor embolization ratio. The Kendall Concordance Coefficient Test was carried out on the mean of the mathematical calculations and the average of the 3 expert visual values. The concordance coefficient was 0.218, P = 0.011. The results confirmed that the mathematical calculations were consistent with the average of the 3 experts.

Correlation coefficient analysis results show that the mathematical calculation value has a linear correlation with the visual results and average values of the 3 experts, Table 5. The correlation coefficient between the mathematical calculation results and the average of the visual results of the 3 diagnostic experts was the highest, r = 0.931, Figure 6.

Discussion

With the continuous advancement of medical technology, the efficacy of selective hepatic artery embolization for primary liver cancer has been recognized by the medical community worldwide. The increasingly mature minimally invasive treatment technology and its obvious curative effect make the interventional therapy represented by selective hepatic artery embolization gradually become the first choice for non-surgical treatment of primary liver cancer. However, there are still many controversies in quantitatively analysis of embolization effects and systematic treatment planning.[14-16] Therefore, quantitative analysis of liver cancer blood supply levels and embolization ratio, and then the development and selection of the best systemic treatment program, is still an important problem in the treatment of liver cancer with selective hepatic artery embolization.

At present, the criteria and methods for determining the blood supply level of solid tumors have not been clearly
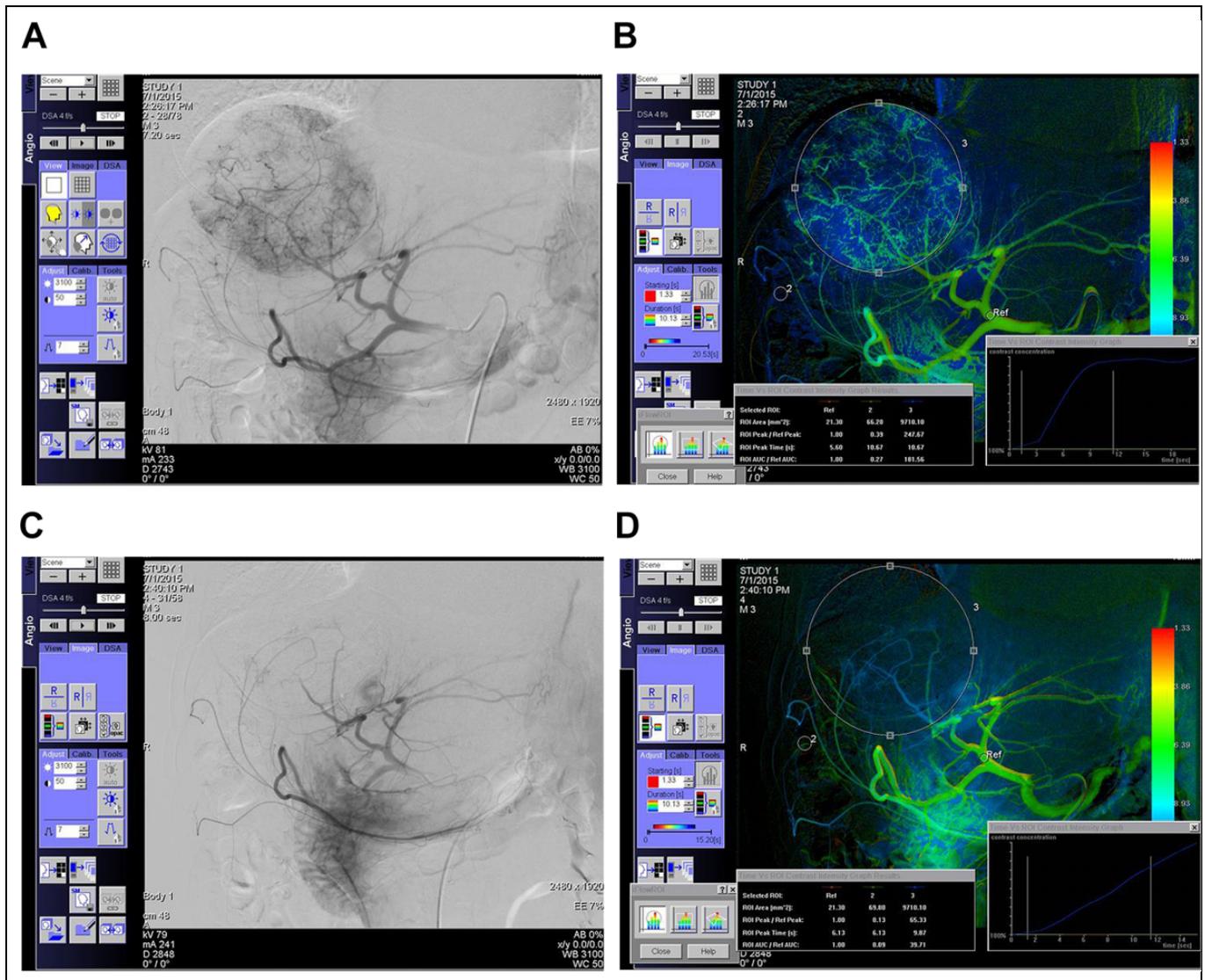
Figure 4. Example of blood supply analysis for liver cancer embolization. (A, B): Tumor blood supply before embolization treatment. (C, D): Tumor blood supply after embolization treatment.

defined in medical clinical practice, or in clinical guidelines such as EASL-EORTC clinical practice guidelines.[17] In a study published in 2013 by Takayasu *et al.*[18] the blood supply level of liver cancer was divided into 2 categories: blood-rich tumor and less blood tumor. The criteria for less blood tumor were described as: in the DSA contrast arterial phase, the tumor area did not enhance or manifested as the same blood supply, compared with the surrounding liver parenchyma. Conversely, a tumor with enhanced performance is defined as a blood-rich tumor. Because such a definition is relatively rough, it is difficult to be used as a therapeutic reference in clinical work, reflecting practical value. In a study published in 2011,[19] Vogl *et al.* described the criteria for less blood tumor as DSA results showed that the blood in the tumor was thin, or the CT scan showed less embolic agent entered the tumor. In Katyal *et al.*'s research, less blood hepatic carcinoma was defined as a primary liver cancer with a degree of enhancement in the arterial phase equal to or less than the surrounding liver parenchyma in a CT-enhanced scan.[20] Kim *et al.* defined the blood supply level of liver cancer based on the degree of tumor enhancement by DSA angiography[21]: in the arterial phase, blood supply is lower than 50% of the surrounding liver parenchyma, which is defined as a less blood tumor, and other tumors were defined as blood-rich tumors.

The above studies all distinguish the blood-rich and less blood liver cancer in simple ways, but the classification methods have not been unified, and there is no evaluation standard for quantitative or stratified evaluation. It is impossible to analyze the complicated blood supply conditions of liver cancers.[19,21]

In addition, the results of previous studies can only be visually estimated by diagnosticians, and there is a lack of

reasonable and effective objective quantitative evaluation methods to support clinical work. In summary, although researchers have made various attempts to evaluate the blood supply of liver cancer, the methods for rational and effective evaluation of tumor blood supply have not been reported so far.

Table 2. Preoperative Blood Supply Level Software Calculation Results and Visual Diagnosis Results.

Number	Software measured value	Diagnostic expert 1	Diagnostic expert 2	Diagnostic expert 3	Mean value of diagnostic experts
1	5.1750	6	6	4	5.3
2	4.2126	6	3	5	4.7
3	7.5345	7	6	5	6.0
4	0.1718	1	1	1	1.0
5	2.2127	3	2	1	2.0
6	1.9288	1	1	3	1.7
7	3.4877	5	3	2	3.3
8	4.3459	4	5	6	5.0
9	8.3771	6	9	6	7.0
10	2.4382	3	2	5	3.3
11	2.3406	3	3	4	3.3
12	5.3166	7	5	5	5.7
13	6.8399	9	7	9	8.3
14	3.6890	7	4	7	6.0
15	2.1217	6	4	5	5.0
16	3.9145	4	5	5	4.7
17	9.7851	9	6	8	7.7
18	9.0826	9	8	6	7.7
19	3.1140	4	5	4	4.3
20	5.7794	6	7	5	6.0
21	0.8567	1	1	2	1.3
22	3.7170	4	5	3	4.0
23	1.4392	1	3	2	2.0
24	6.7213	5	8	8	7.0
25	1.5050	2	2	4	2.7
26	6.3174	6	8	7	7.0
27	2.5835	2	5	3	3.3
28	5.4984	7	8	9	8.0
29	2.1013	2	4	2	2.7
30	2.2038	2	4	5	3.7

Based on the analysis characteristics of the I-flow program, the research team designed a method to calculate the blood supply level of liver cancer by using the initial part of the hepatic artery as a reference point. The method utilized the image workstation to acquire contrast agent enhancement data within the tumor, which reduced the errors estimated by the human eyes. The experimental results showed that the consistency of the evaluation of tumor blood supply levels by different diagnostic experts was lacking. Although the diagnostic expert's visual evaluation has certain defects, it is currently the most commonly used and relied on in clinical practice. There is no more effective evaluation method or gold standard for evaluation. Therefore, research on methods that can objectively and quantitatively assess tumor blood supply levels has become an important issue that needs to be resolved urgently in clinical practice.

The measurement method designed by this research group can relatively effectively evaluate the preoperative blood supply of liver cancers and obtained a high consistency with the average of the visual results of the diagnostic experts, which made up for the difference of the diagnostic experts due to subjective factors. The experiment confirmed that the method proposed by this research group has the potential to be an effective means to evaluate the blood supply level of tumors. By comparing this evaluation method with the average results estimated by the diagnostic experts, we obtained positive results in all embolization surgery results, confirming that this evaluation method has a high sensitivity.

In the transcatheter arterial embolization (TAE) treatment of solid tumors, accurate evaluation of tumor blood supply changes before and after embolization treatment is of great significance for the estimation of treatment effect and prognosis. At present, according to clinical experience, scholars recommend using low-dose chemotherapy agent when using TAE to treat primary liver cancer.[22,23] Because the use of high-dose chemotherapy agent in TAE does not significantly improve the anti-cancer effect, and there is no significant difference in efficacy between high-dose and low-dose chemotherapeutic agent.[24,25] Moreover, the use of low-dose chemotherapy agent in TAE is conducive to maintaining the status of liver function and reducing the incidence of liver

Table 3. Analysis of Correlation Coefficients of Tumor Blood Supply Levels by Different Methods (r: Correlation Coefficient).

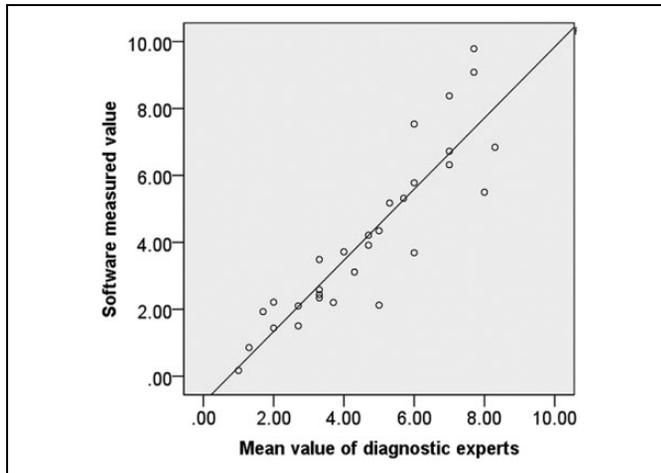|	Software measured value	Diagnostic expert 1	Diagnostic expert 2	Diagnostic expert 3	Mean value of diagnostic experts
Software measured value	-	r = 0.866, P < 0.01	r = 0.880, P < 0.01	r = 0.769, P < 0.01	r = 0.918, P < 0.01
Diagnostic expert 1	r = 0.866, P < 0.01	-	r = 0.724, P < 0.01	r = 0.761, P < 0.01	r = 0.917, P < 0.01
Diagnostic expert 2	r = 0.880, P < 0.01	r = 0.724, P < 0.01	-	r = 0.723, P < 0.01	r = 0.895, P < 0.01
Diagnostic expert 3	r = 0.769, P < 0.01	r = 0.761, P < 0.01	r = 0.723, P < 0.01	-	r = 0.907, P < 0.01
Mean value of diagnostic experts	r = 0.918, P < 0.01	r = 0.917, P < 0.01	r = 0.895, P < 0.01	r = 0.907, P < 0.01	-

Figure 5. Correlation analysis between the value measured by the software and the average visual value of 3 diagnostic experts (correlation coefficient r = 0.918)

Table 4. Comparison of Software Measurement Results With Expert Visual Results for Tumor Embolization Ratio(%).

Number	Software measured value	Diagnostic expert 1	Diagnostic expert 2	Diagnostic expert 3	Mean value of diagnostic experts
1	34.6409	30.00	50.00	20.00	33.33
2	92.8574	95.00	75.00	90.00	86.67
3	104.011	100.00	100.00	100.00	100.00
4	47.1731	55.00	35.00	45.00	45.00
5	109.1702	100.00	100.00	100.00	100.00
6	71.5549	80.00	55.00	70.00	68.33
7	28.8786	45.00	30.00	20.00	31.67
8	77.7131	80.00	60.00	85.00	75.00
9	88.6550	85.00	95.00	90.00	90.00
10	64.0496	70.00	55.00	75.00	66.67
11	47.2096	40.00	55.00	50.00	48.33
12	47.3171	50.00	35.00	55.00	46.67
13	81.4712	80.00	85.00	70.00	78.33
14	91.5301	90.00	85.00	90.00	88.33
15	60.3572	45.00	60.00	60.00	55.00
16	89.7714	80.00	95.00	90.00	88.33
17	82.7341	90.00	85.00	70.00	81.67
18	79.1096	80.00	70.00	85.00	78.33
19	80.8464	90.00	75.00	70.00	78.33
20	79.6567	80.00	85.00	65.00	76.67
21	55.4249	40.00	60.00	40.00	46.67
22	89.4627	90.00	75.00	95.00	86.67
23	86.7731	85.00	80.00	80.00	81.67
24	91.9341	90.00	95.00	90.00	91.67
25	66.2577	50.00	70.00	45.00	55.00
26	66.9862	70.00	60.00	85.00	71.67
27	46.2193	55.00	40.00	60.00	51.67
28	38.6495	50.00	70.00	50.00	56.67
29	66.0958	90.00	90.00	80.00	86.67
30	90.2521	90.00	90.00	80.00	86.67

fibrosis.[26,27] Therefore, the therapeutic effect of TAE mainly depends on the embolization of the tumor feeding artery.[28,29] However, in many patients, the tumor volume of liver cancers is too large, due to the limited tolerance of patients to embolization treatment, or the problems of liver function damage or insufficient liver function reserve, the dose of hepatic artery embolization is often limited. In clinical practice, the proportion of liver cancers that can achieve complete embolization in one treatment is not high, and many patients require multiple embolizations.[9] Assessing the proportion of each tumor embolization treatment can not only help a single efficacy prediction, but also an important data support for a split embolization treatment program.

Different studies have confirmed that different embolization ratios are closely related to the effect of tumor interventional therapy and the prognosis of patients with liver cancer.[20,21] There is no uniform conclusion in the academic community regarding the delineation of the level of embolization for selective arterial embolization. Some scholars have suggested that embolization blocking tumor blood supply could be divided into completely filling, basic filling, and partial filling.[10-12] Some scholars have proposed to divide the embolization rate into more than 75%, 50%-74%, less than 49%.[30] However, because there is no effective method to quantitatively evaluate the embolization rate of hepatic artery embolization treatment, these classification criteria lack clinical data support, which is greatly reduced in practicality.

Vogl TJ et al[30] pointed out that the embolization ratio of TAE has important clinical value. Because of the lack of a single embolization ratio, the number of TAEs must increase, resulting in increased drug resistance of tumor cells, tumor blood vessels must be damaged and become narrow or occluded, and blood-rich tumors may become less blood supply type. At the same time, normal liver tissue may also have cirrhosis due to the influence of drugs, or the degree of cirrhosis of the original liver may be aggravated, so as to affect the curative effect and even interrupt the treatment.[28,31,32] However, previous studies have failed to give a feasible measurement method to obtain accurate tumor embolization ratio.

Based on the image analysis workstation, this research group used the method of contrast analysis of tumor intensities before and after embolization to evaluate the proportion of tumor blood supply reduction after embolization treatment, which achieved the quantitative evaluation of tumor embolization ratio. The experimental results showed that the results measured by this method were highly consistent with the average of the evaluation results of 3 senior diagnostic experts, and the relatively highest correlation coefficient was obtained, which bridged the differences in the subjective assessment results of different diagnostic experts. The above results illustrated that the quantitative analysis of the tumor embolization ratio evaluation method designed by the research team through the image processing workstation reduced the error caused by the subjective cognition of the diagnostic personnel to some extent, so that the measurement data with more clinical reference value can be obtained, which has a high practicality.

With the rapid development of interventional medicine and the unremitting efforts of interventional scholars, transarterial embolization technology has been widely used in clinical

Table 5. Correlation Coefficient Analysis of Results of Different Methods for Evaluating Tumor Embolization Ratio (r: Correlation Coefficient).

	Software measured value	Diagnostic expert 1	Diagnostic expert 2	Diagnostic expert 3	Mean value of diagnostic experts
Software measured value	-	r = 0.886, P < 0.01	r = 0.847, P < 0.01	r = 0.872, P < 0.01	r = 0.931, P < 0.01
Diagnostic expert 1	r = 0.886, P < 0.01	-	r = 0.781, P < 0.01	r = 0.836, P < 0.01	r = 0.907, P < 0.01
Diagnostic expert 2	r = 0.847, P < 0.01	r = 0.781, P < 0.01	-	r = 0.726, P < 0.01	r = 0.926, P < 0.01
Diagnostic expert 3	r = 0.872, P < 0.01	r = 0.836, P < 0.01	r = 0.726, P < 0.01	-	r = 0.915, P < 0.01
Mean value of diagnostic experts	r = 0.931, P < 0.01	r = 0.907, P < 0.01	r = 0.926, P < 0.01	r = 0.915, P < 0.01	-
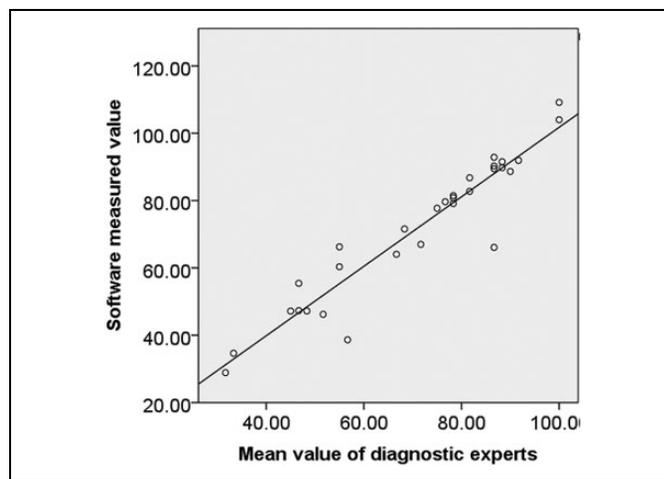
Figure 6. Correlation analysis between the value measured by the software and the average visual value of 3 diagnostic experts (correlation coefficient r = 0.931)

practice. The comprehensive treatment mode based on hepatic artery embolization had become a standardized and preferred treatment for advanced unresectable liver cancer, and with the maturity of the technology, TAE's indications are becoming wider and wider. However, due to the differences in individual patients, medical environment and medical technology, some patients with advanced liver cancer were not ideal after interventional therapy, and the difference in survival period was also relatively large. Because the blood supply level and embolization ratio of liver cancer could not be quantitatively evaluated, the therapeutic effects of different levels and experiences of medical institutions were quite different, which was an important issue that restricted the digitization and standardization of embolization treatment.

Therefore, how to accurately assess the blood supply level and embolization filling rate of liver cancer through effective and convenient methods, so as to develop the individualized treatment plan, reduce the influence of adverse factors on prognosis, and achieve the effect of precise treatment, is the most concern problem of cancer interventional therapy doctors. Through quantitative assessment, tumor embolization treatment can improve the level of digitization, reduce the dependence of treatment planning and evaluation on the subjective experience of doctors, and make the planning and sustainability of treatment have a higher level of evidence. Quantitative evaluation methods can effectively reduce the differences between different medical institutions due to the subjective factors of doctors, so as to maximize the patient's treatment benefits, reflecting the higher clinical practical value and socio-economic value.

Ethical Statement

Our study was approved by The Medical Ethics Committee of Tianjin Cancer Hospital (approval no. E2018295). All patients provided written informed consent prior to enrollment in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

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