Computer-aided evaluation of cataract surgery; a metric comparison of continuous circular capsulorhexis by trainee and specialist surgeons

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Study Group:

ABSTRACT

TITLE: Computer-aided evaluation of cataract surgery; a metric comparison of continuous circular capsulorhexis by trainee and specialist surgeons.

ABSTRACT BODY:

Purpose: There is a correlation between the centration and quality of the continuous circular capsulorhexis (CCC) and the subsequent refractive outcomes in cataract surgery. We developed a novel software evaluation tool based on video processing to assess the execution of CCC by comparing trainee and specialist surgeons from a teaching hospital. The software incorporates a novel performance metric that quantifies their performance.

Methods: We first detected the limbus of the eye in each video frame using Hough circle detection. Next, the capsulorhexis forceps is detected based on its linearity and specularity. Then a visual tool-tracking function is invoked based on an image similarity measure which is illumination invariant and computationally inexpensive. The number of capsular grasps is then found from a functional plot of distance between the pair of forceps tips. Other parameters computed include surgical efficiency with respect to surgical time, circularity index and absolute decentration of the CCC with respect to the optical centre. These parameters are integrated into a single novel performance metric for each surgery (Fig 1).

Results: The software was implemented in MATLAB and we evaluated 35 capsulorhexis videos of surgeries done by 19 specialist and 16 trainee surgeons. The quantitative parameters for all videos are listed in Fig 2. A student t-test comparison of the mean performance metric scores found that the trainee group scored 0.4244 (±0.2) which was significantly lower than the specialist group which scored 0.8676 (±0.1) (P=0.0001), indicating that the two groups could be differentiated.

Conclusions: We developed a tool for evaluation of the performance of capsulorhexis during cataract surgery. The proposed performance metric computed by the software could differentiate the two groups of surgeons. Using quantitative parameters, we can have an objective and repeatable way for surgical assessment to identify areas for improvement.

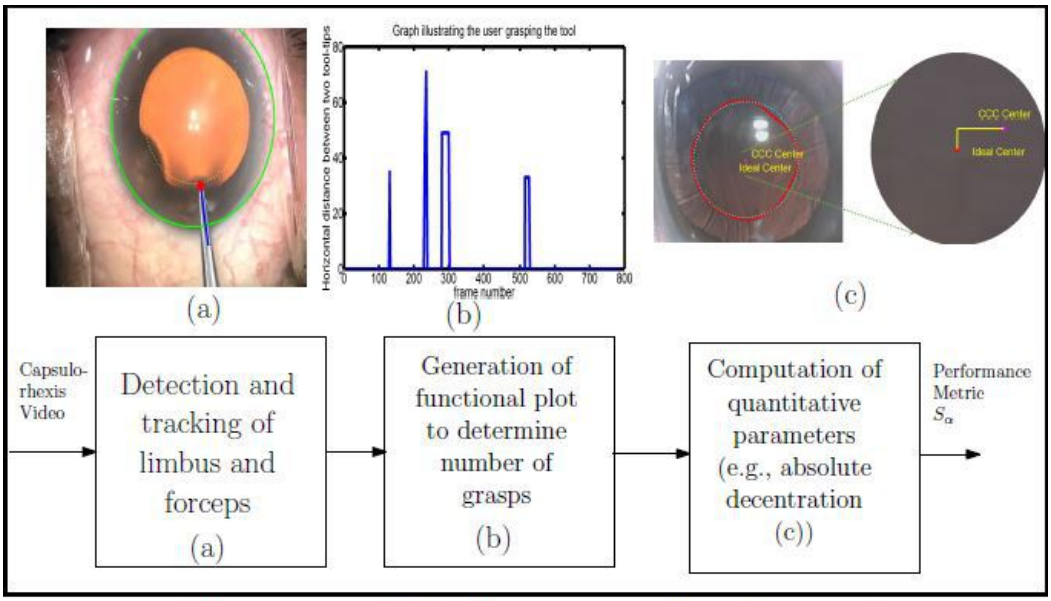

Fig 1(i): Three main modules of the compuer-aided evaluation software.

Performance metric $S_\alpha = \begin{cases} \frac{g}{t} \times \beta \times \theta \times \gamma, & \text{if } CI \geq \alpha \\ 0, & \text{otherwise,} \end{cases}$

where circularity index $CI = \frac{4\pi * area\ of\ the\ CCC}{(perimeter\ of\ the\ CCC)^2}$,

α: lower limit of circularity index

g: total grasp time

t: total capsulorhexis operation time

$\beta = \begin{cases} 1, & \text{if } n \leq \rho \\ e^{-\frac{(n-\rho)}{10}}, & \text{otherwise} \end{cases}$

n: number of grasps

ρ: upper limit of number of grasps

is the penalty for exceeding ρ
(1 means no penalty),

$\theta = \begin{cases} 1, & \text{if } t \leq \tau \\ e^{-\frac{t}{10\tau}}, & \text{otherwise} \end{cases}$

τ: upper limit of time for capsulorhexis

is the penalty for exceeding τ,

$\gamma = \begin{cases} 1, & \text{if } AD \leq \varepsilon \\ e^{-\frac{(AD-\varepsilon)}{10}}, & \text{otherwise} \end{cases}$

ε: upper limit of absolute decentration

is the penalty for exceeding ε,
where absolute decentration
$AD = ||rhexis\ center - ideal\ CCC\ center||$

Fig 1(ii): Metric computation.

Fig.1 Computer-aided metric evaluation for CCC.

S.No.	Efficiency (%)	Number of tool grasps (n)	circularity index	absolute decentration (pixels)	performance metric S_α ($\alpha = 0.95$)
1	93.12	3	0.9935	7	0.9312
2	91.57	9	0.9870	1	0.9157
3	78.34	7	0.9900	2	0.7834
4	90.94	3	0.9931	4	0.9094
5	96.21	4	0.9949	2	0.9621
6	64.38	6	0.9892	7	0.6438
7	96.74	2	0.9583	5	0.9674
8	72.57	7	0.9923	1	0.7257
9	61.78	6	0.9865	3	0.6178
10	90.99	5	0.9871	4	0.9099
11	81.55	9	0.9839	4	0.8155
12	97.67	4	0.9899	5	0.9767
13	94.77	6	0.9877	2	0.9477
14	65.96	7	0.9900	3	0.6596
15	95.34	1	0.9756	6	0.9534
16	94.85	1	0.9879	4	0.9485
17	97.29	3	0.9789	2	0.9729
18	90.73	3	0.9880	4	0.9073
19	93.62	6	0.9939	1	0.9362
Average Values	86.76 %	5	0.9900	3 pixels	0.8676

(a)

S.No.	Efficiency (%)	Number of tool grasps (n)	circularity index	absolute decentration (pixels)	performance metric S_α ($\alpha = 0.95$)
1	72	17	0.9969	14	0.1478
2	55.17	7	0.9908	10	0.3500
3	74.62	13	0.9922	5	0.4436
4	69.76	12	0.9951	5	0.4950
5	83.23	6	0.9923	7	0.6814
6	66.43	27	0.9960	10	0.4658
7	82.31	5	0.9897	6	0.8231
8	70.70	2	0.9931	5	0.6281
9	64.52	9	0.9451	20	0(CI<α)
10	50.30	12	0.9478	20	0(CI<α)
11	64.44	9	0.9869	6	0.6444
12	46.60	10	0.9799	7	0.3925
13	54.32	2	0.9821	12	0.4743
14	53.03	8	0.9895	6	0.4751
15	63.16	4	0.9835	9	0.5171
16	25.17	7	0.9962	6	0.2517
Average Values	62.24	9	0.9848	9 pixels	0.4244

(b)

Fig.2. Performance parameters of (a) specialist and (b) trainee surgeons performing capsulorhexis.

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