포항공과대학교
산업경영공학과

전북대학교병원
CHONBUK NATIONAL UNIVERSITY HOSPITAL

Ergonomic Design
Technology Lab

Development of a User-Centered Virtual Liver Surgery System

Xiaopeng Yang[1], Wonsup Lee[1],Younggeun Choi[1], and Heecheon You[1]
Ji Hyun Kim[2], Hee Chul Yu[2], and Baik Hwan Cho[2]

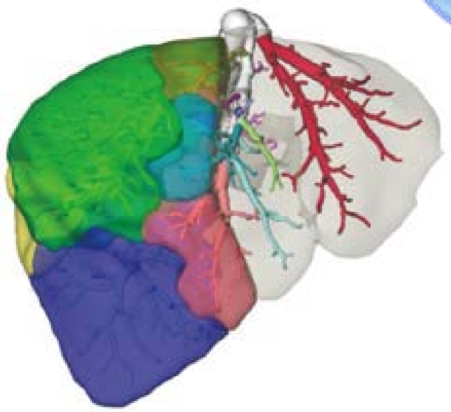
[1]Dept. of Industrial & Management Eng., POSTECH
[2]Dept. of Surgery, Chonbuk National Univ. Medical School

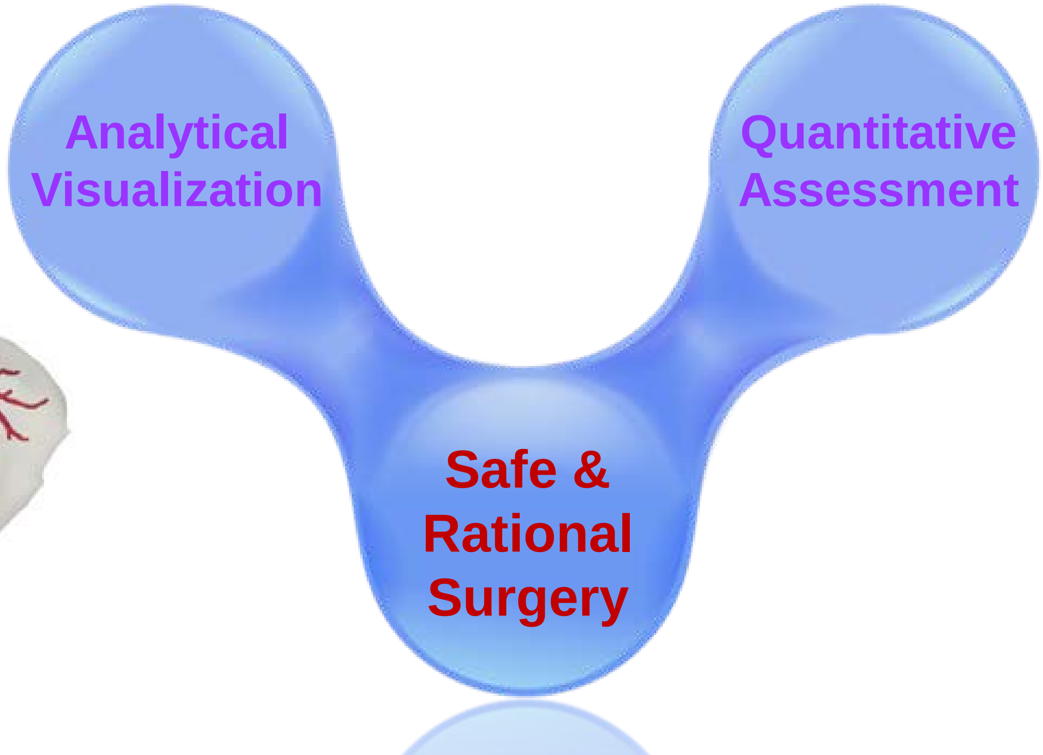
Agenda

- Introduction
  - Background
  - Objectives of the Study
- Use Scenario & Demo of Dr. Liver
- Performance evaluation
- Future Study

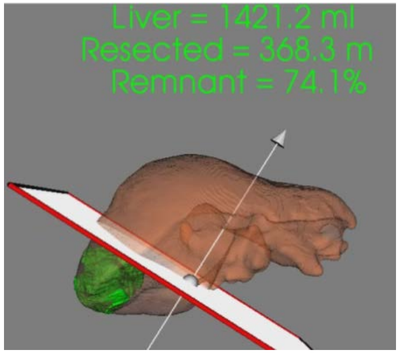
Values of 3D Virtual Liver Surgery System

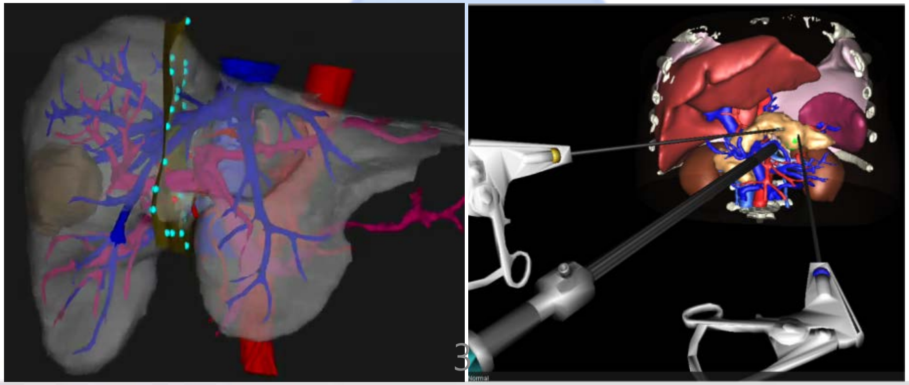
- Vascular structure
- Location & size of tumor
- Segmentation of the liver



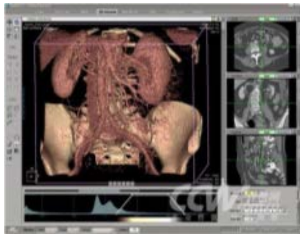
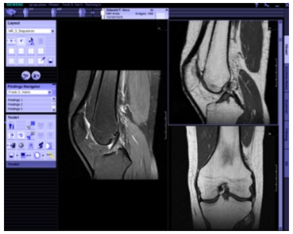
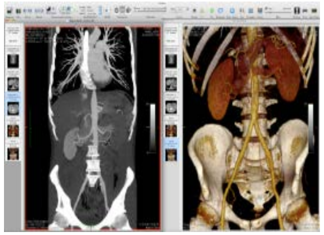

Analytical Visualization
Quantitative Assessment
Safe & Rational Surgery

- Volumetry of the liver
- Volumetry of the remnant and/or graft


Liver = 1421.2 ml
Resected = 368.3 m
Remnant = 74.1%

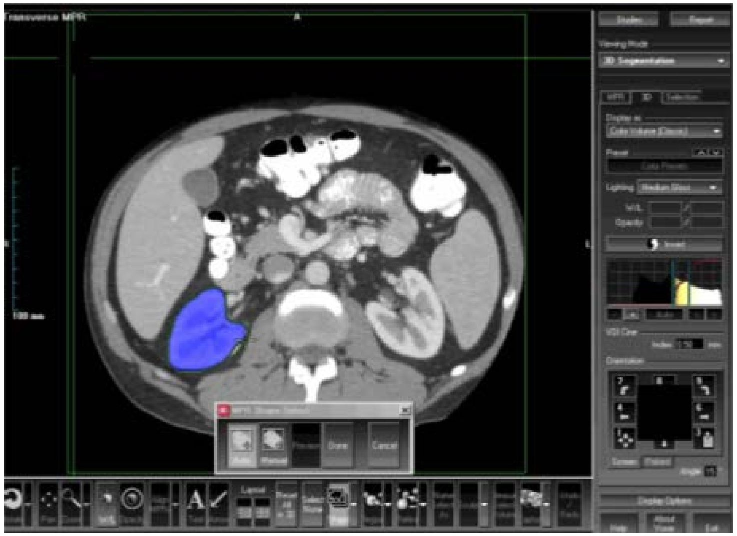


Virtual Surgery Systems: Generic

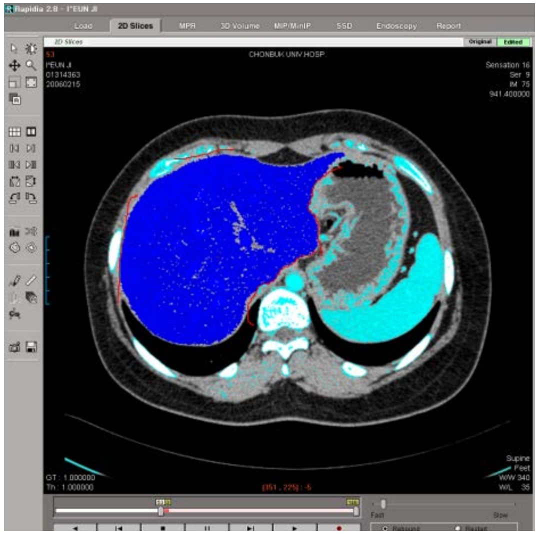
	Rapidia (Infinitt)	**Voxar 3D (Barco ⇒ Toshiba)**	**Syngo.via (Simense)**	**OsiriX (Freeware - Pixmeo)**
				
Country	Korea	Japan	Germany	Swiss
System features	● 3D visualization ● Measurement ● Options ✓ Colon & polyps ✓ Cardiac Ca ✓ Vessel ✓ Brain angio	● 3D visualization ● Measurement ● Options ✓ Colon ✓ Cardiac Ca ✓ Vessel	● Oncology ✓ PET & CT segmentation (extraction) ✓ CT Lung CAD ✓ Colonography ● Cardiology ✓ Vascular ✓ Cardiac ✓ Ca Scoring ● Neurology ✓ PET evaluation ✓ Perfusion CT	● 3D visualization ● Measurement ● Options ✓ Custom plugins ✓ iPhone, iPad compatible

Liver Extraction: Manual & Semi-Automatic

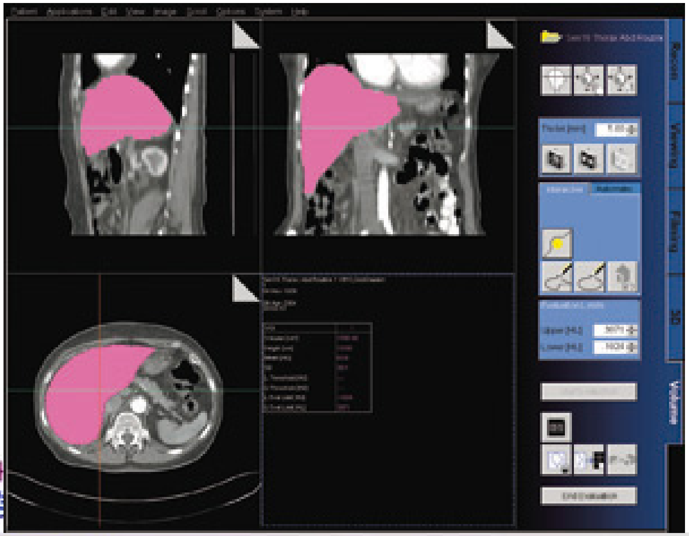
Voxar 3D


Transverse MPR
Studies
Report
Viewing Mode
3D Segmentation

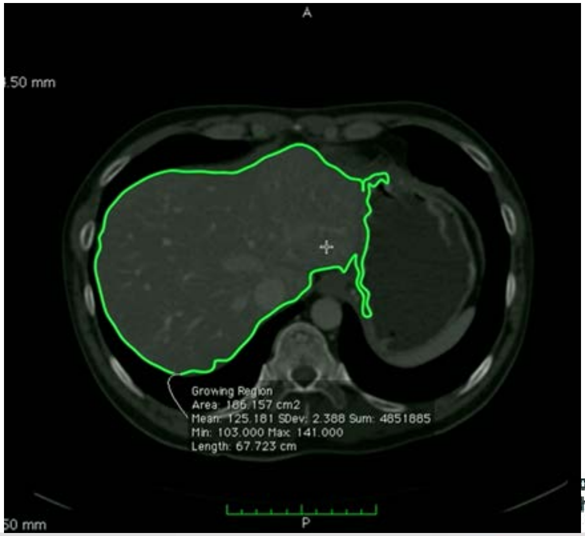
Rapidia


Rapidia 2.8
Load
2D Slices
MPR
3D Volume
MIP/MinIP
SSD
Endoscopy
Report
CHONBUK UNIV HOSP

Syngo.via



OsiriX

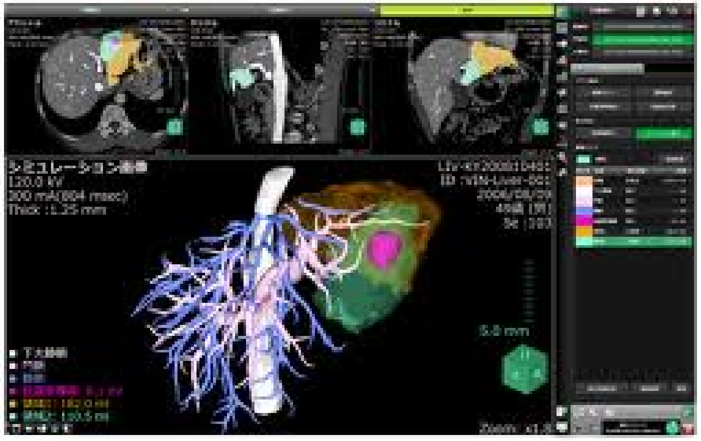

A
.50 mm
P
50 mm

Growing Region
Area: 186.157 cm2
Mean: 125.181 SDev: 2.388 Sum: 4851885
Min: 103.000 Max: 141.000
Length: 67.723 cm

Synapse Vincent

	Synapse Vincent (Fujifilm)
Country	Japan
System features	● Specialized liver functions ✓ Liver extraction ✓ Vessel analysis ✓ Segmentation ✓ Volumetry ✓ Surgery planning

ボリュームアナライザー
SYNAPSE VINCENT



Visia™ Liver-Distant Services

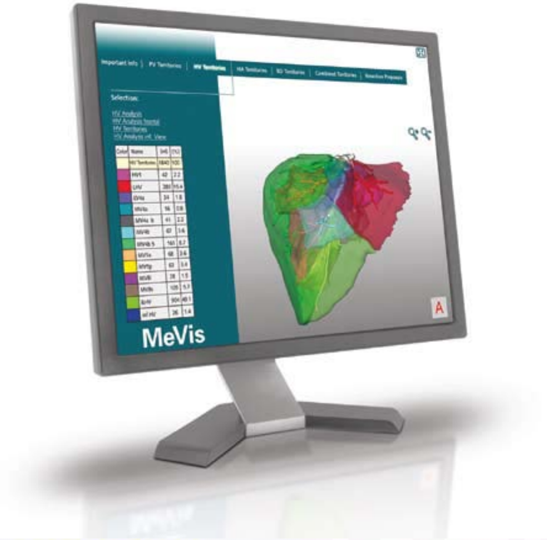
- MeVis Medical Solutions AG
- LiverAnalyzer & LiverViewer developed using MeVisLab
- Analysis services

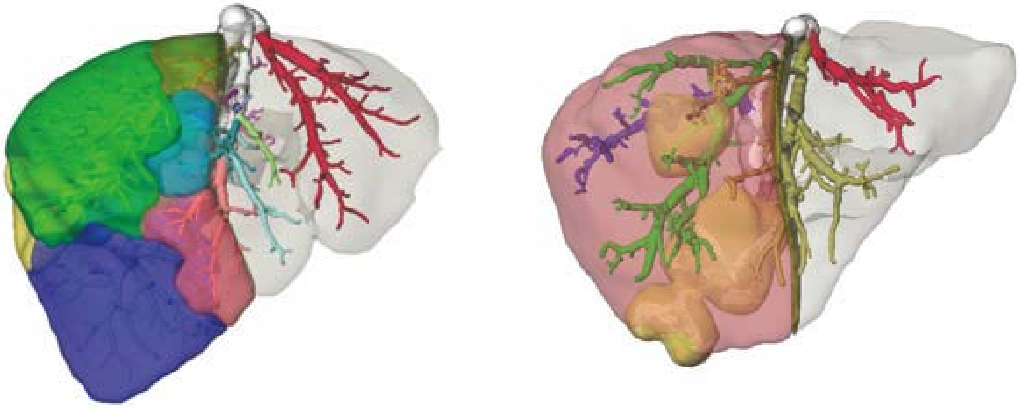
  - Segmentation of the liver, veins, biliary system, and tumors

  - Volumetric data for both remnant and/or graft

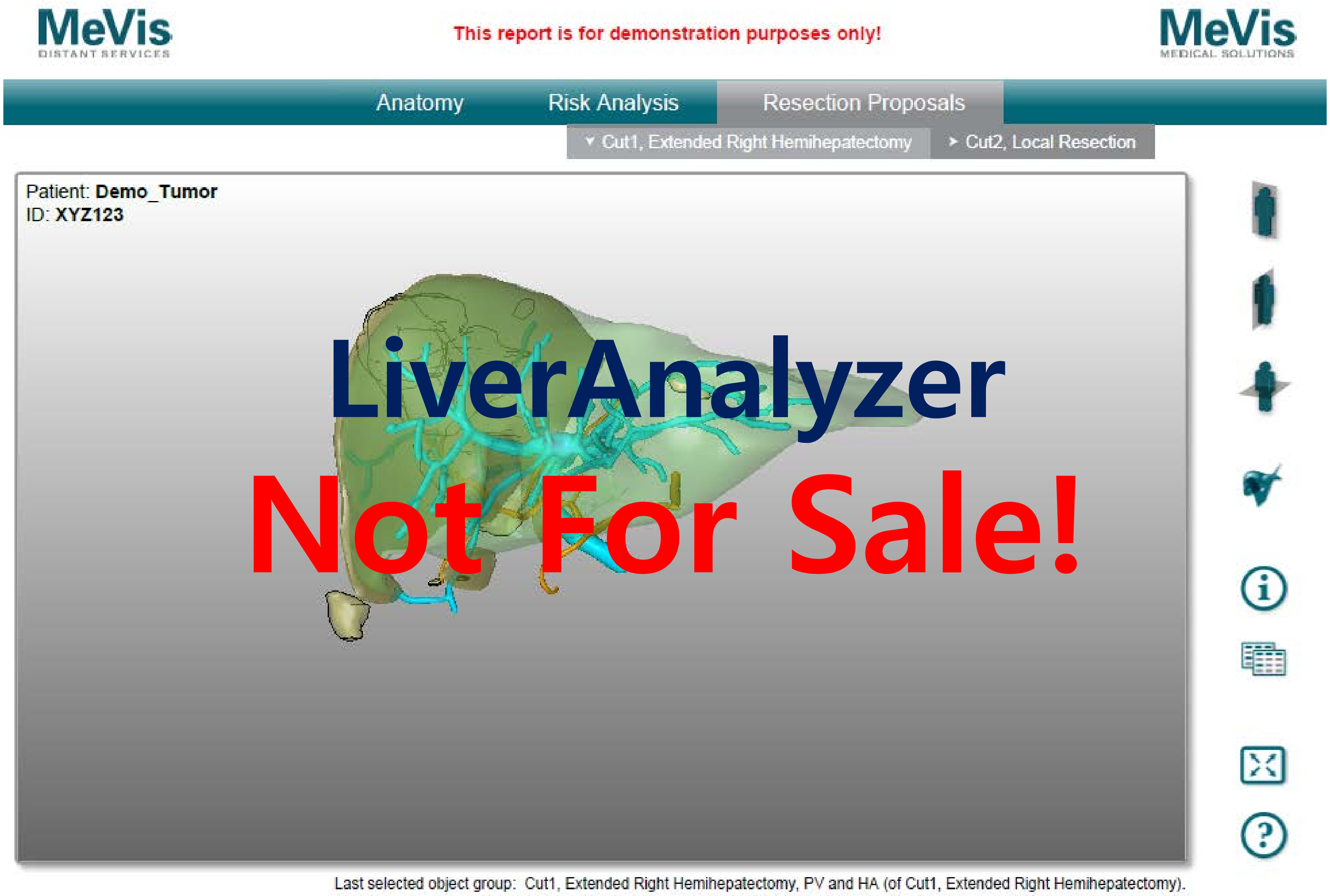
  - Vascular territory evaluation

  - Virtual resection options





Surgery Planning – Oncological Case


MeVis
DISTANT SERVICES
MeVis
MEDICAL SOLUTIONS
Anatomy
Risk Analysis
Resection Proposals
▾ Cut1, Extended Right Hemihepatectomy
▸ Cut2, Local Resection

This report is for demonstration purposes only!

Patient: **Demo_Tumor**
ID: **XYZ123**

LiverAnalyzer

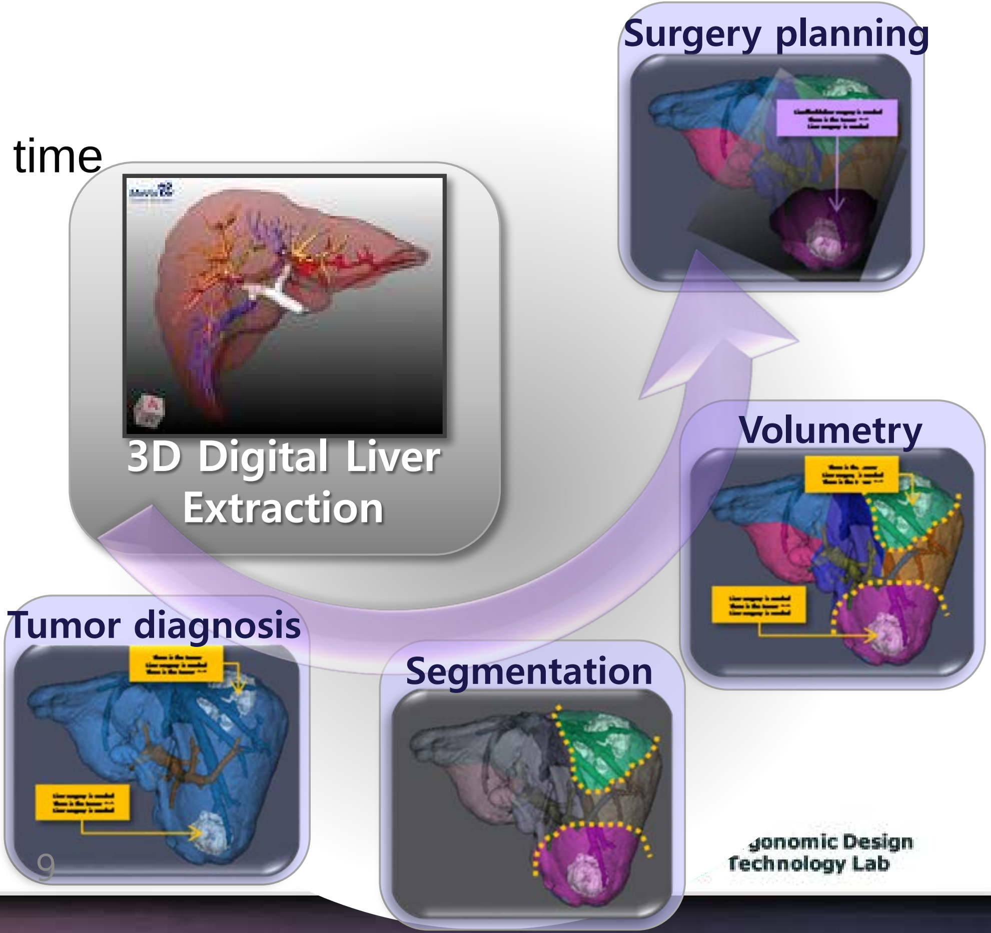
Not For Sale!

Last selected object group: Cut1, Extended Right Hemihepatectomy, PV and HA (of Cut1, Extended Right Hemihepatectomy).

Objectives of the Study

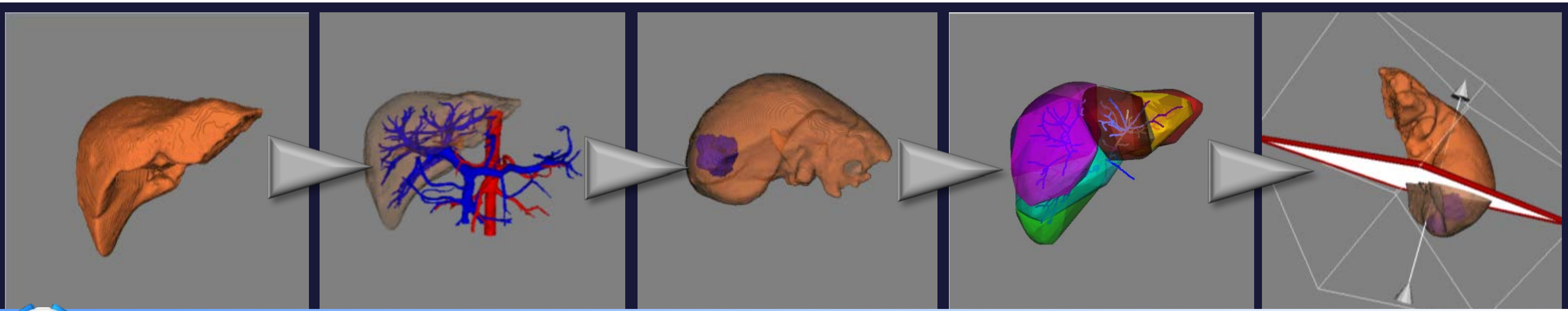
Development of a user-friendly virtual liver surgery system: Dr. Liver

1. Specialized functions to liver surgery
2. Intelligent decision support information
3. Intuitive, user-friendly interface
4. Acceptable information processing time



Surgery planning
3D Digital Liver Extraction
Volumetry
Tumor diagnosis
Segmentation

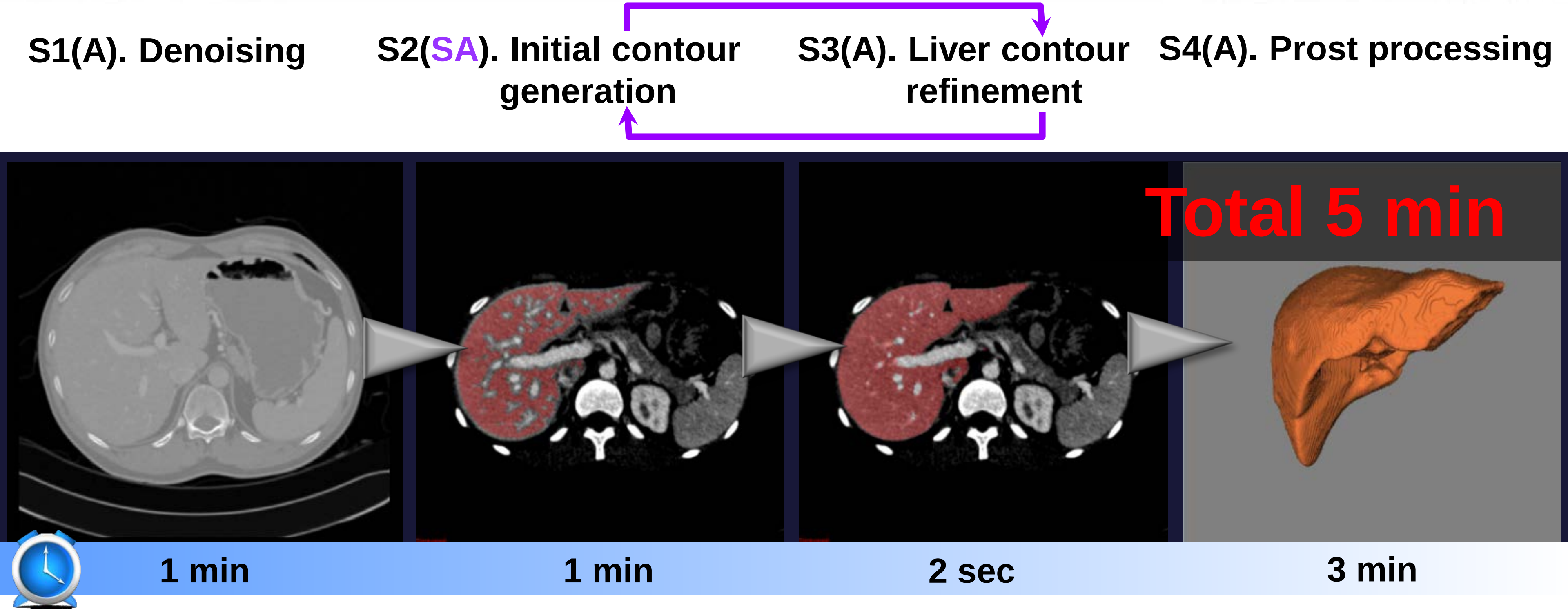
Use Scenario: System Overview



Liver extraction	Vessel extraction	Tumor extraction	Liver segmentation	Surgery planning
5 min	5 ~ 10 min	5 min	5 min	5 min

Entire processing time: 25 ~ 30 min

Use Scenario: Liver Extraction


S1(A). Denoising

S2(SA). Initial contour generation

S3(A). Liver contour refinement

S4(A). Prost processing

1 min

1 min

2 sec

3 min

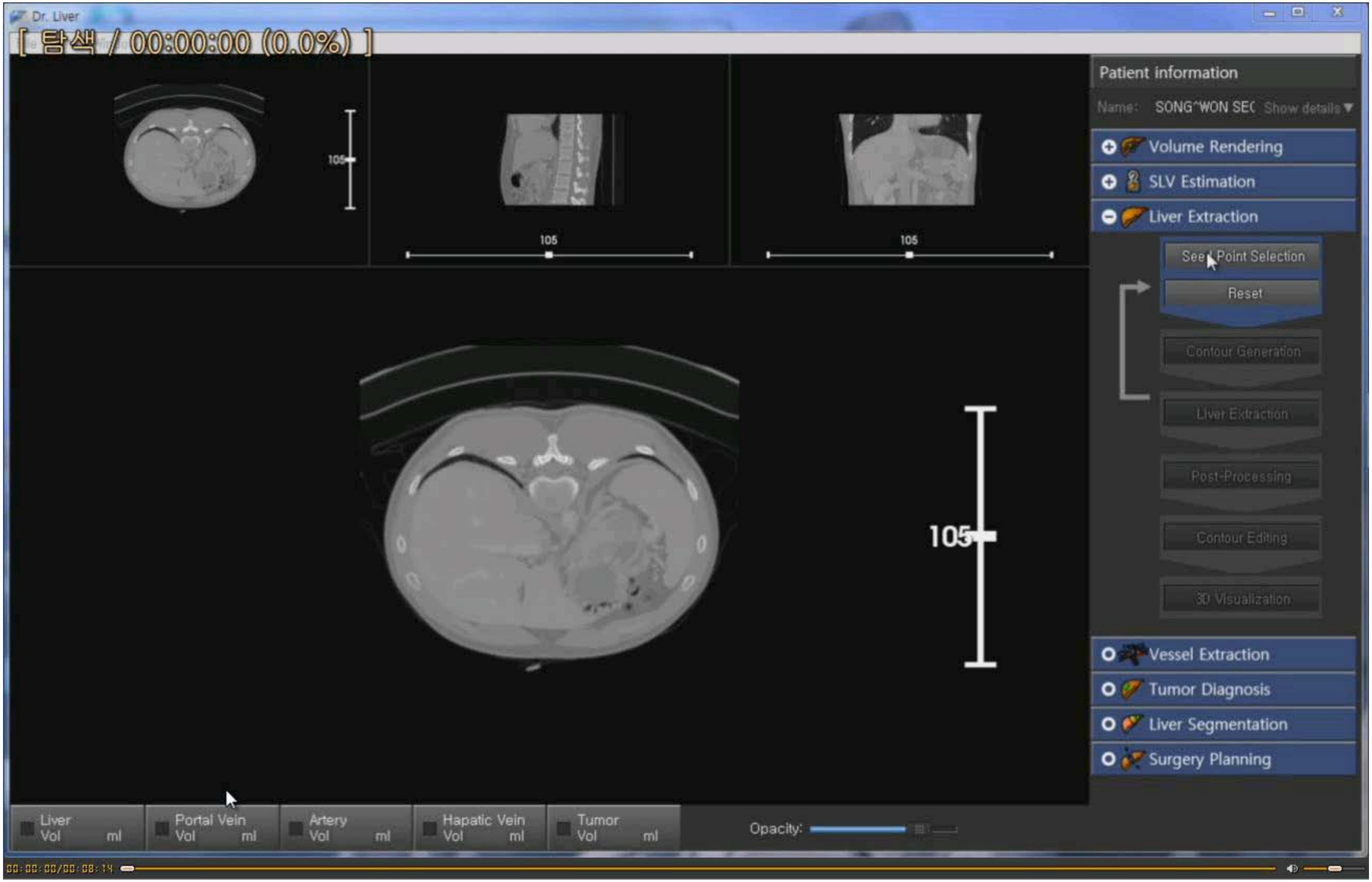
- **Noise removing** in CT images

- **Multiple seed points selection** on liver using the mouse
- **Initial liver contour generation** using fast marching level set method

- **Liver contour refinement** using threshold level set method
- Liver contour **verification**

- Hole filling and liver surface smoothing
- Unwanted part elimination

Demo: Liver Extraction

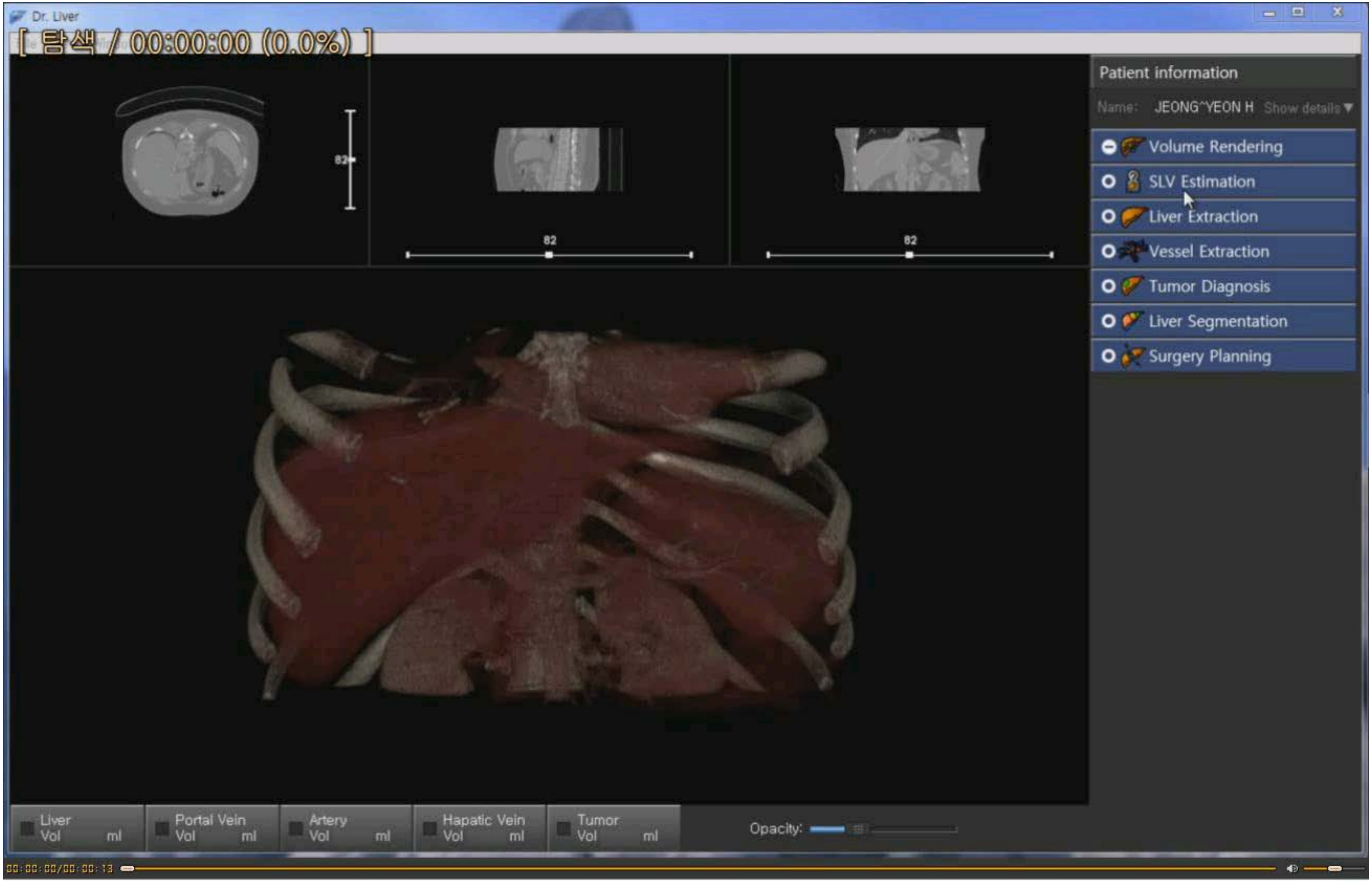


Patient information

Name: SONG^WON SE(Show details ▼

Dr. Liver
[탐색 / 00:00:00 (0.0%)]
105
105
105
105
Volume Rendering
SLV Estimation
Liver Extraction
Seed Point Selection
Reset
Contour Generation
Liver Extraction
Post-Processing
Contour Editing
3D Visualization
Vessel Extraction
Tumor Diagnosis
Liver Segmentation
Surgery Planning
Liver Vol ml
Portal Vein Vol ml
Artery Vol ml
Hapatic Vein Vol ml
Tumor Vol ml
Opacity:
00:00:00/00:08:14

Demo: SLV Estimation


Dr. Liver
[탐색 / 00:00:00 (0.0%)]
82
82
82
Patient information

Name: JEONG^YEON H

Show details ▼
Volume Rendering
SLV Estimation
Liver Extraction
Vessel Extraction
Tumor Diagnosis
Liver Segmentation
Surgery Planning
Liver Vol ml
Portal Vein Vol ml
Artery Vol ml
Hapatic Vein Vol ml
Tumor Vol ml
Opacity:
00:00:00/00:00:13

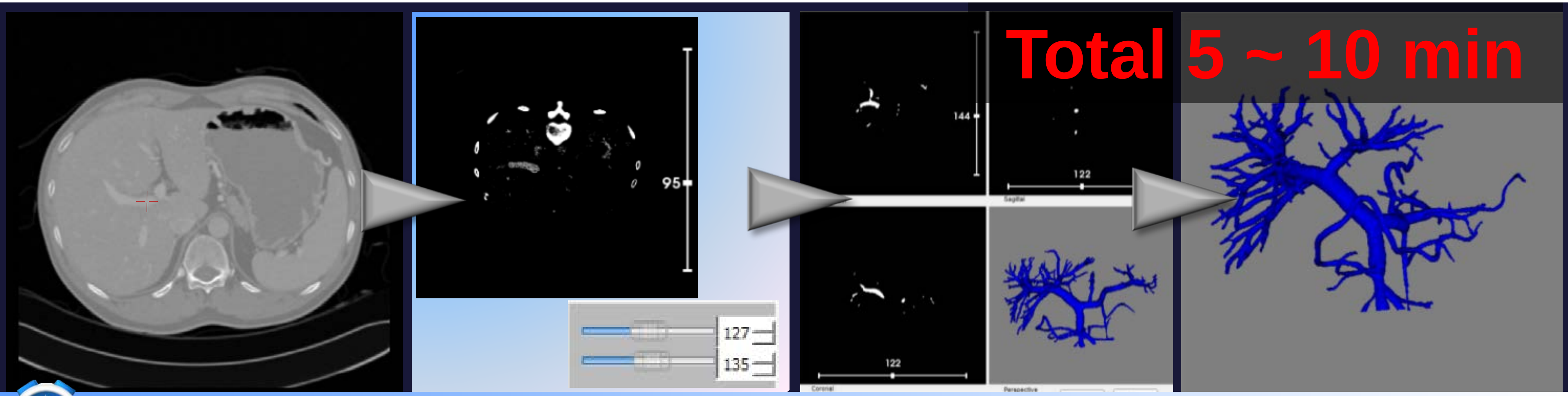
Use Scenario: Vessel Extraction

S1(M). Seed point selection

S2(M). Interactive threshold interval identification

S3(A). Vessel extraction

S4(A). Prost processing



Total 5 ~ 10 min

1 sec	10 sec	1 min	3 min

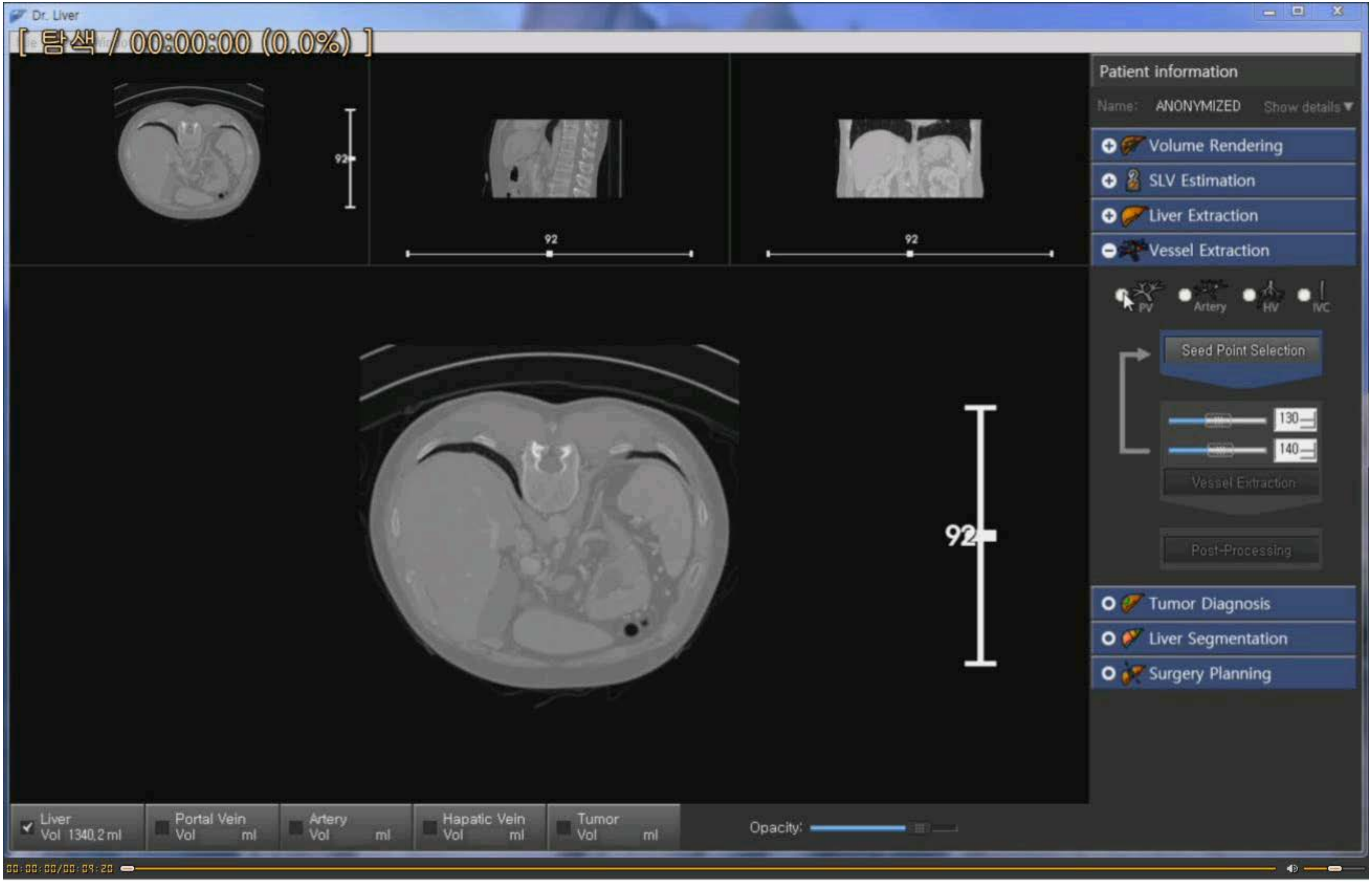
- **Single seed point selection** on vessel for region growing using the mouse

- **Threshold interval identification** using slider bars

- **Vessel extraction** using region growing method
- Extracted vessel **verification**

- Hole filling

Demo: Vessel Extraction



Dr. Liver
[탐색 / 00:00:00 (0.0%)]
92
92
92
92
Patient information
Show details ▼
Volume Rendering
SLV Estimation
Liver Extraction
Vessel Extraction
PV
Artery
HV
IVC
Seed Point Selection
130
140
Vessel Extraction
Post-Processing
Tumor Diagnosis
Liver Segmentation
Surgery Planning
Portal Vein Vol ml
Artery Vol ml
Hapatic Vein Vol ml
Tumor Vol ml
Opacity:
00:00:00/00:09:20

Name: ANONYMIZED

☑ Liver Vol 1340.2 ml

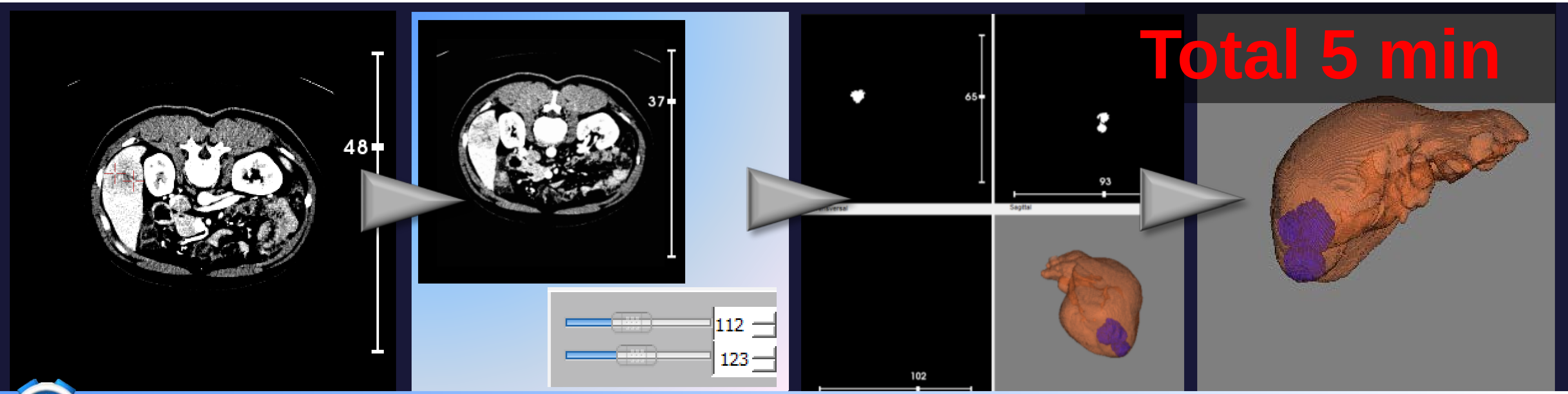
Use Scenario: Tumor Extraction

S1(M). Seed point selection

S2(M). Interactive threshold interval identification

S3(A). Tumor extraction

S4(A). Prost processing



Total 5 min

10 sec

10 sec

1 min

3 min

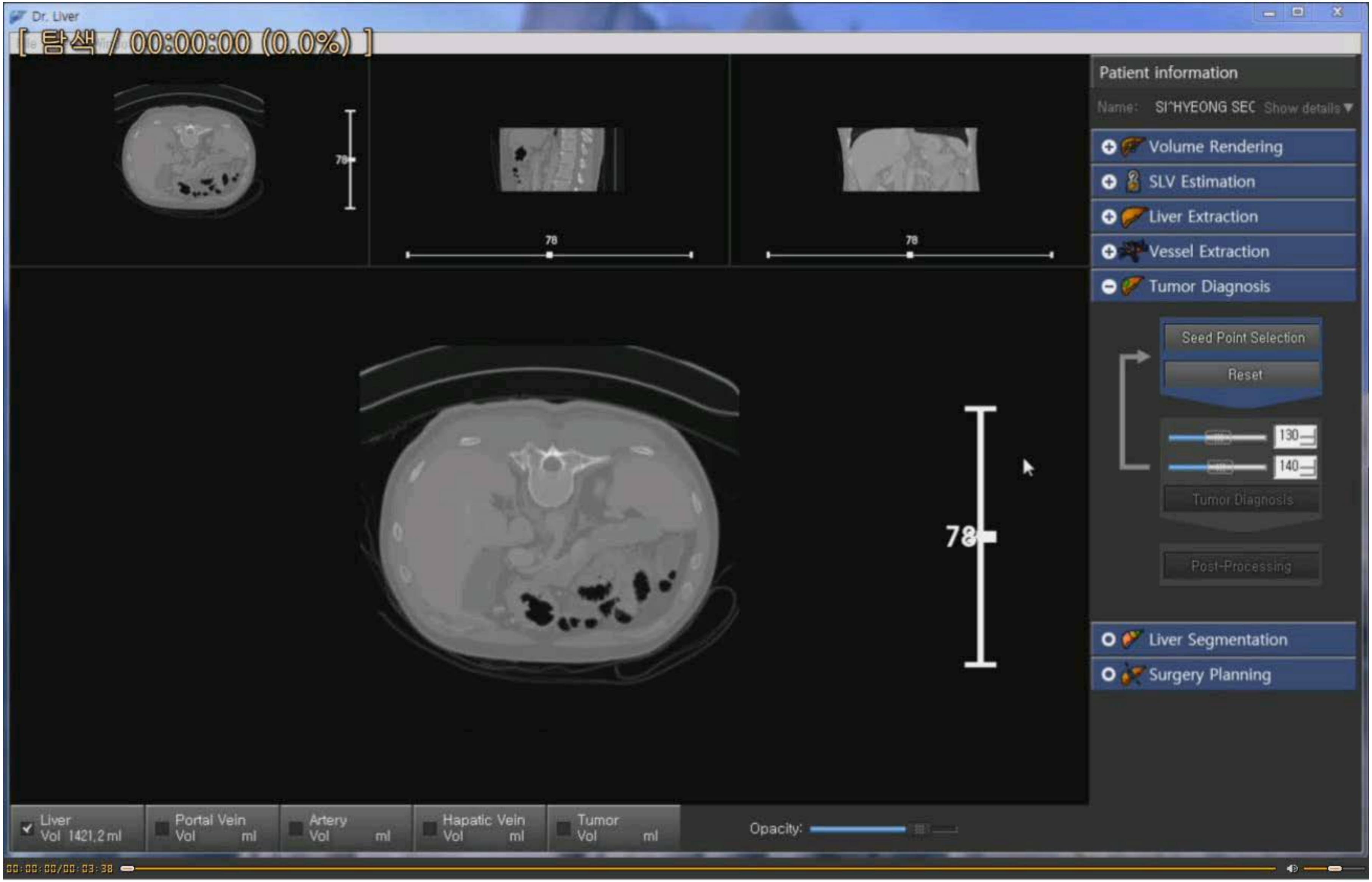
- **Multiple seed point selection** on tumor using the mouse

- **Threshold interval identification** using slider bars

- **Tumor extraction** using threshold level set method
- **Diagnosis verification**: false identification, missing

- Hole filling & smoothing

Demo: Tumor Extraction


Dr. Liver
[탐색 / 00:00:00 (0.0%)]
78
78
78
78
Patient information
Show details ▼
Volume Rendering
SLV Estimation
Liver Extraction
Vessel Extraction
Tumor Diagnosis
Seed Point Selection
Reset
Tumor Diagnosis
Post-Processing
Liver Segmentation
Surgery Planning
Portal Vein
Artery
Hapatic Vein
Tumor
Opacity:
00:00:00/00:03:38

Name: SI^HYEONG SEC

130

140

☑ Liver Vol 1421.2 ml

☐ Portal Vein Vol ml

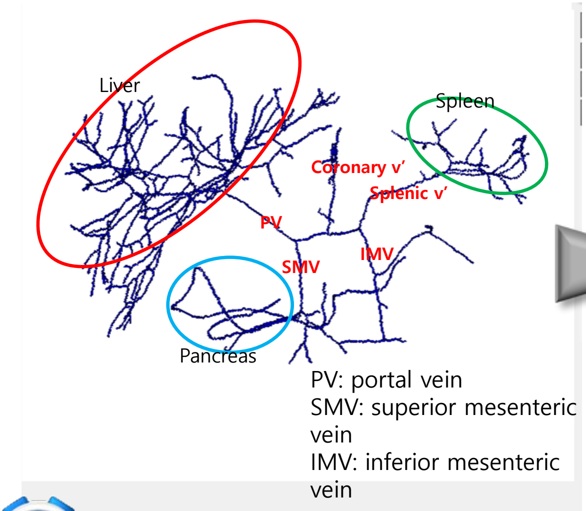
☐ Artery Vol ml

☐ Hapatic Vein Vol ml

☐ Tumor Vol ml

Use Scenario: Segmentation

S1(A). Vessel skeletonization

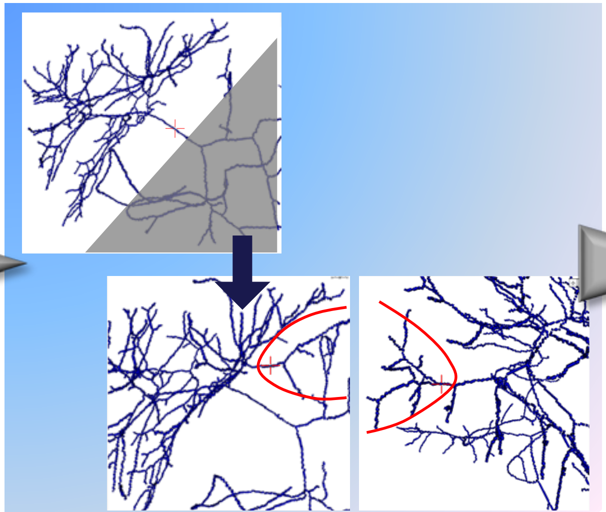


PV: portal vein
SMV: superior mesenteric vein
IMV: inferior mesenteric vein

1 min

- Portal vein thinning

S2(M). Vessel branch selection

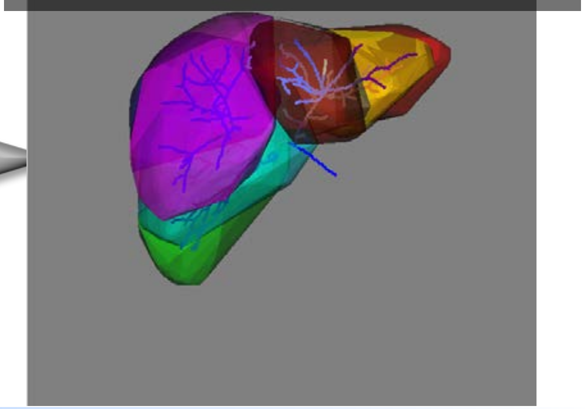


1 min

- **Cutting point selection** using the mouse for cutting portal vein
- **Portal vein branch selection** using the mouse for segmentation

S3(A). Liver segmentation & volume estimation

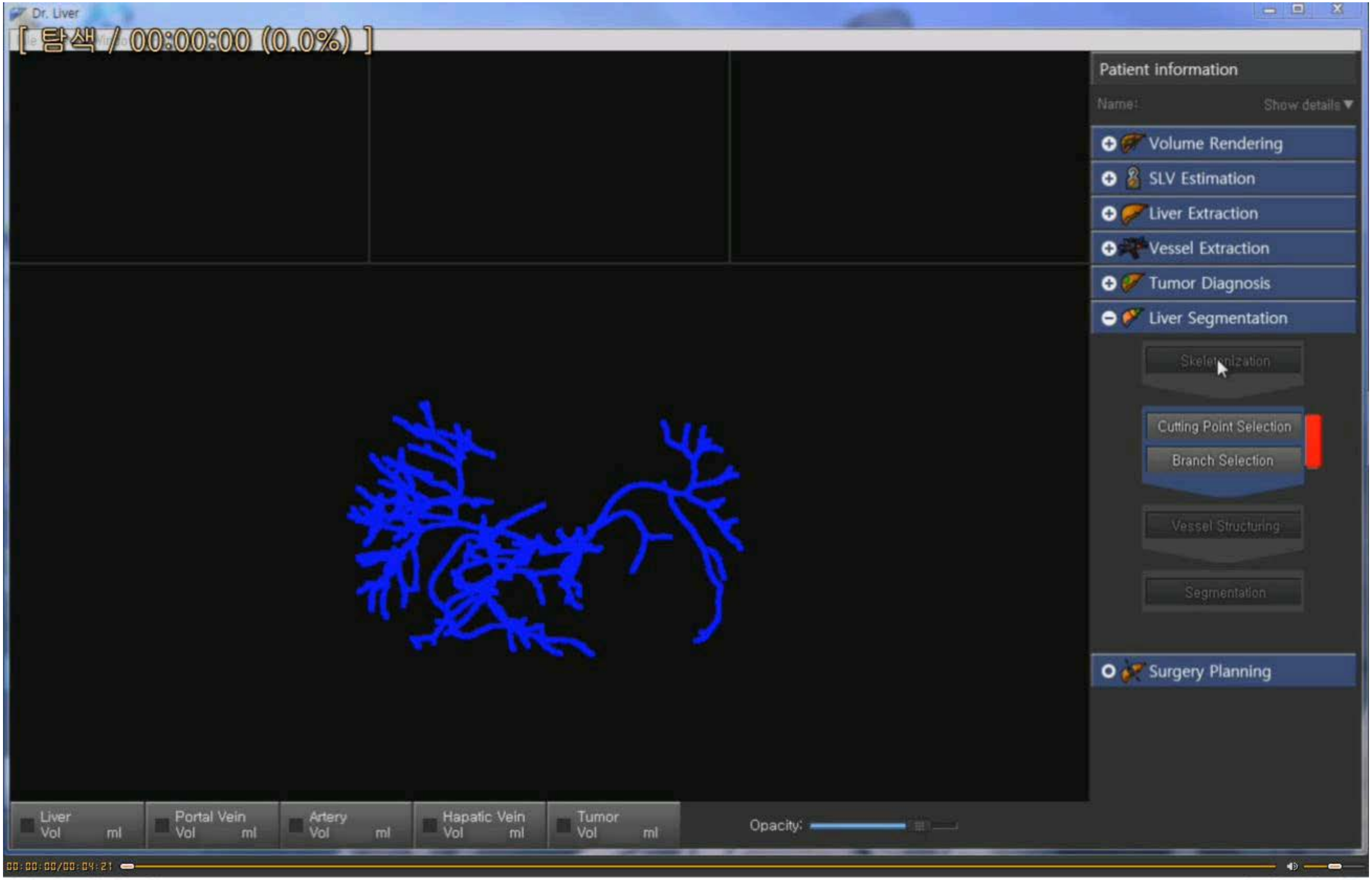
Total 3 min



1 min

- **Liver segmentation**
- Segment result verification
- Coloring
- **Volume estimation for each segment**

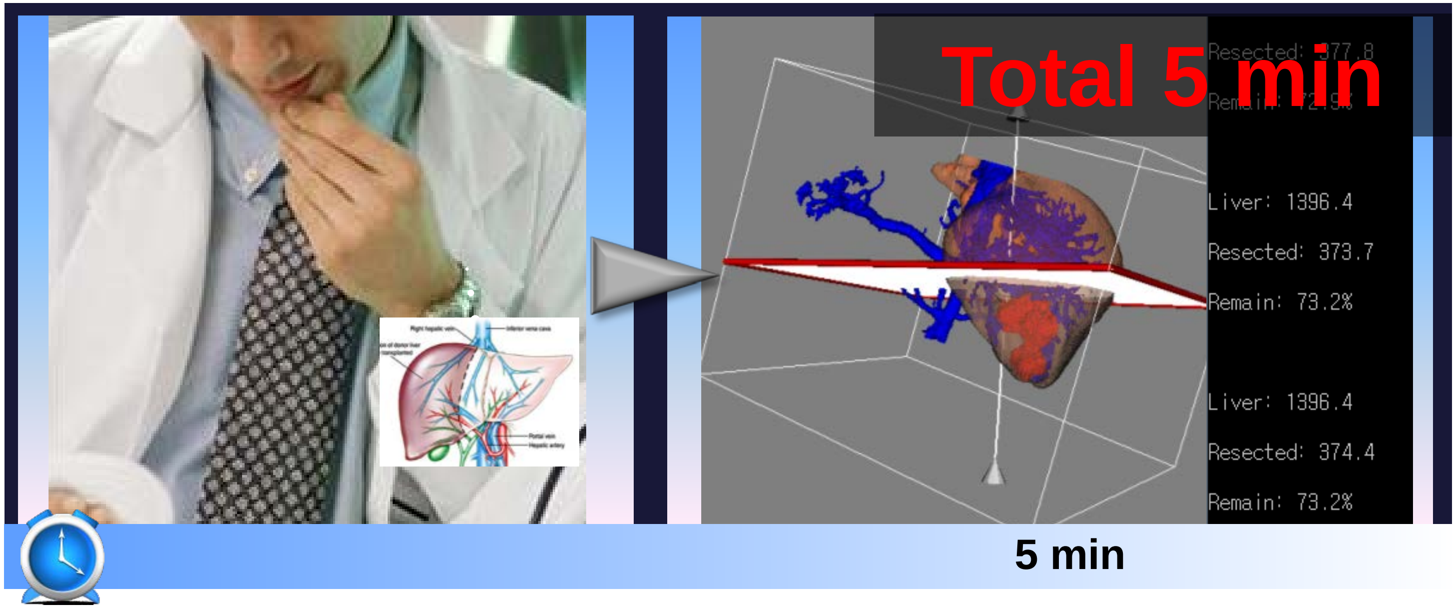
Demo: Liver Segmentation


Dr. Liver
[탐색 / 00:00:00 (0.0%)]
Patient information
Name:
Show details ▼
Volume Rendering
SLV Estimation
Liver Extraction
Vessel Extraction
Tumor Diagnosis
Liver Segmentation
Skeletonization
Cutting Point Selection
Branch Selection
Vessel Structuring
Segmentation
Surgery Planning
Liver Vol ml
Portal Vein Vol ml
Artery Vol ml
Hapatic Vein Vol ml
Tumor Vol ml
Opacity:
00:00:00/00:04:21

Use Scenario: Surgery Planning

S1(M). Surgery method determination

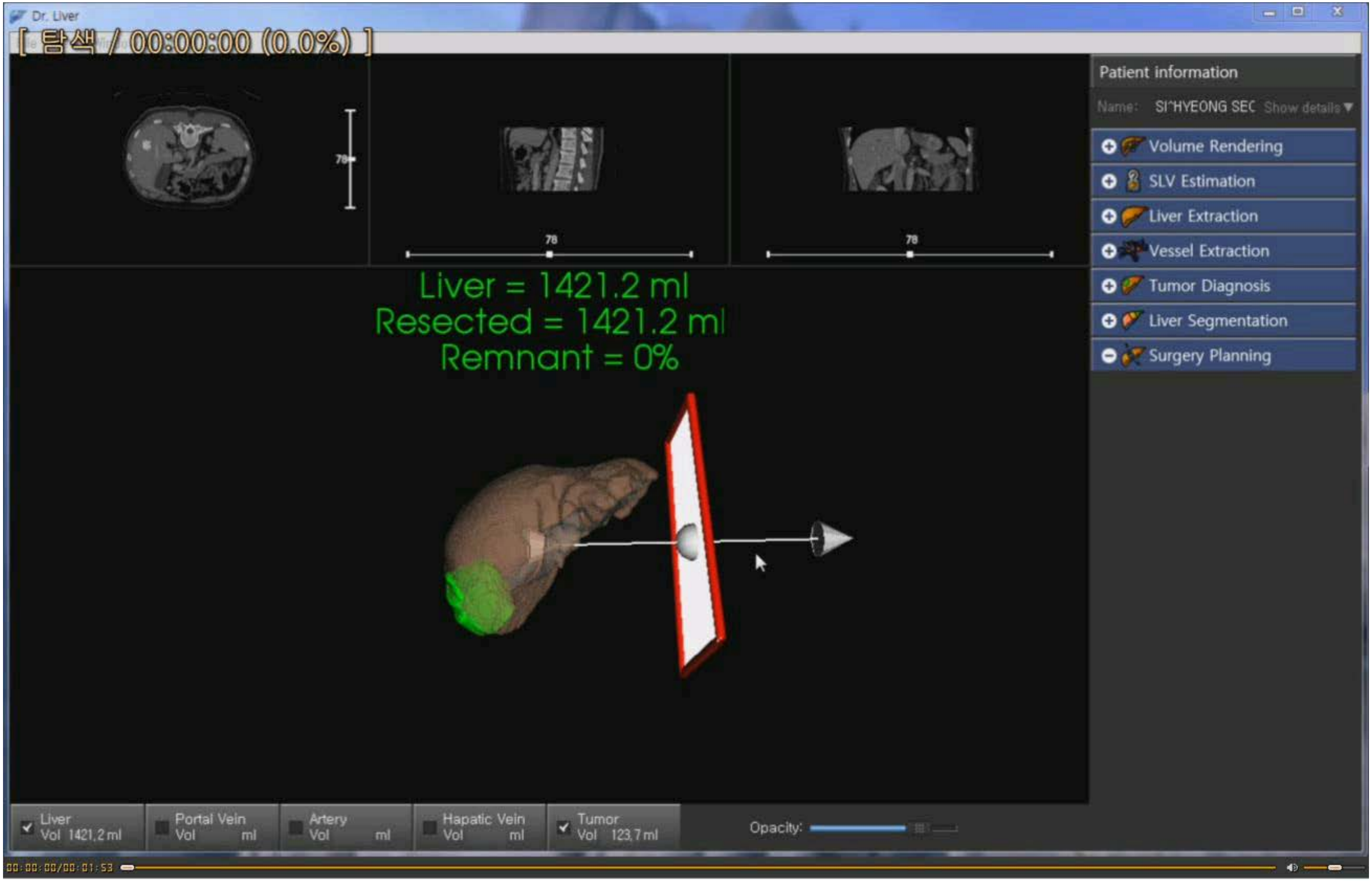
S2(SA). Optimal surgery planning support


Total 5 min
Resected: 377.8
Remain: 72.9%
Liver: 1396.4
Resected: 373.7
Remain: 73.2%
Liver: 1396.4
Resected: 374.4
Remain: 73.2%
5 min

- **Liver surgery method** (transplantation & resection) **selection** based on **volume estimation and vessel analysis results**

- Optimal resection location, surface, and angle for surgery planning
- Safety margin and affected venous branch identification
- Real-time volume calculation of remaining liver parenchyma

Demo: Surgery Planning



Dr. Liver

[탐색 / 00:00:00 (0.0%)]

Patient information

Name: SI^HYEONG SEC

Liver = 1421.2 ml
Resected = 1421.2 ml
Remnant = 0%

☑ Liver Vol 1421,2 ml

☐ Portal Vein Vol ml

☐ Artery Vol ml

☐ Hapatic Vein Vol ml

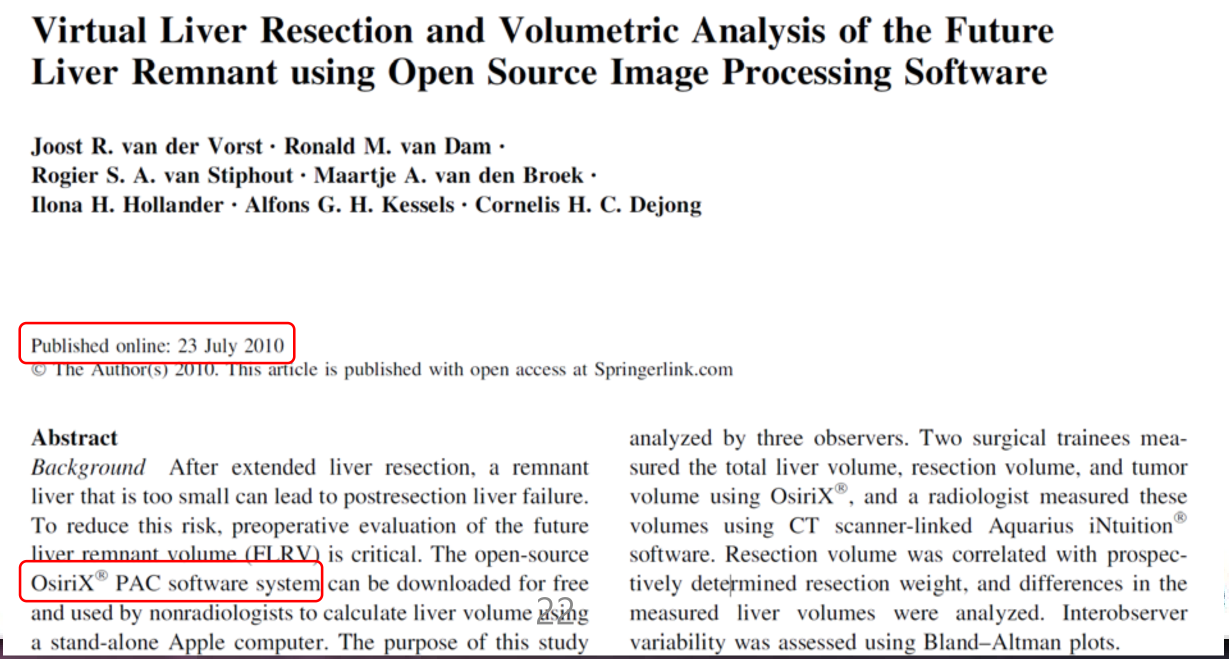
☑ Tumor Vol 123,7 ml

00:00:00/00:01:53

Show details ▼
Volume Rendering
SLV Estimation
Liver Extraction
Vessel Extraction
Tumor Diagnosis
Liver Segmentation
Surgery Planning
78
78
78
Opacity:

Comparison with OsiriX: Liver Extraction

	Dr. Liver	**OsiriX**			
Method	Hybrid method	Region growing			
		2D Auto	2D Auto & Editing	3D Auto	3D Auto & Editing
Procedure	• 10~15 seed points • Initial liver contour detection • Contour refinement	• Liver extraction slice by slice • One seed point for each slice	+ • Manual editing	• Liver extraction based on entire volume data • One single seed point	+ • Manual editing



Virtual Liver Resection and Volumetric Analysis of the Future Liver Remnant using Open Source Image Processing Software

Joost R. van der Vorst · Ronald M. van Dam ·
Rogier S. A. van Stiphout · Maartje A. van den Broek ·
Ilona H. Hollander · Alfons G. H. Kessels · Cornelis H. C. Dejong

Published online: 23 July 2010
© The Author(s) 2010. This article is published with open access at Springerlink.com

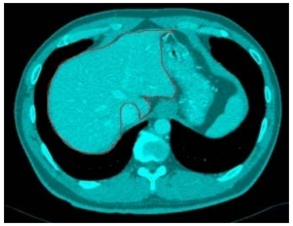
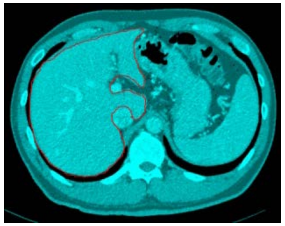
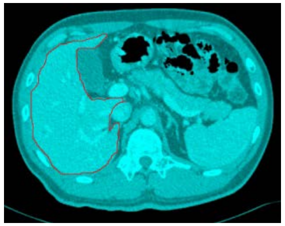
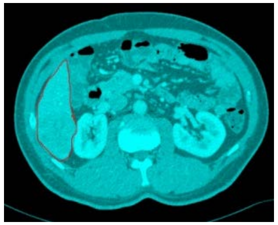
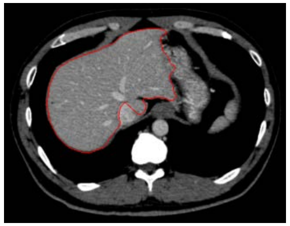
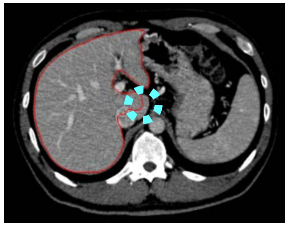
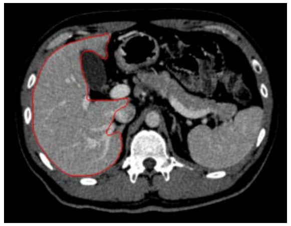
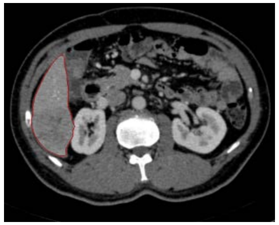
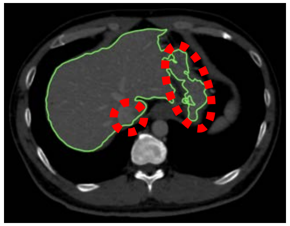
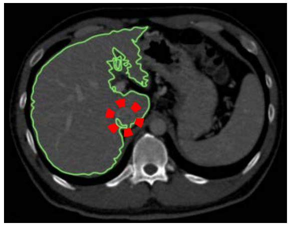
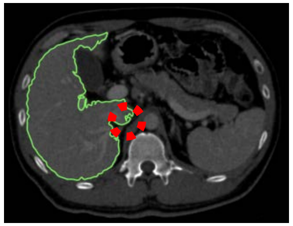
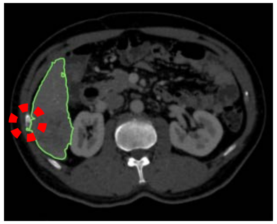
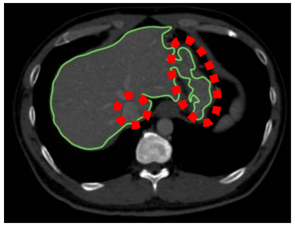
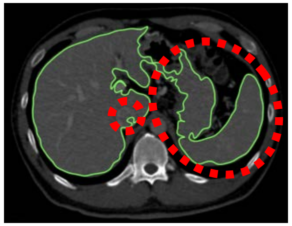
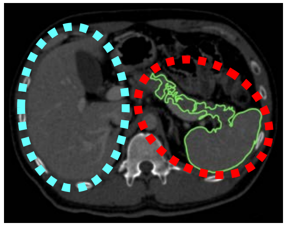
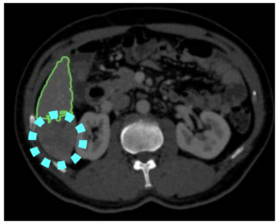
Abstract

Background After extended liver resection, a remnant liver that is too small can lead to postresection liver failure. To reduce this risk, preoperative evaluation of the future liver remnant volume (FLRV) is critical. The open-source OsiriX® PAC software system can be downloaded for free and used by nonradiologists to calculate liver volume using a stand-alone Apple computer. The purpose of this study analyzed by three observers. Two surgical trainees measured the total liver volume, resection volume, and tumor volume using OsiriX®, and a radiologist measured these volumes using CT scanner-linked Aquarius iNtuition® software. Resection volume was correlated with prospectively determined resection weight, and differences in the measured liver volumes were analyzed. Interobserver variability was assessed using Bland–Altman plots.

Performance Comparison: Visual Inspection

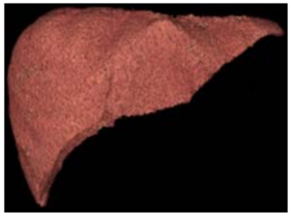
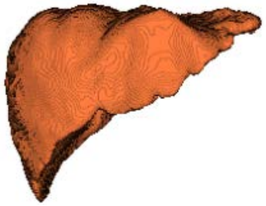
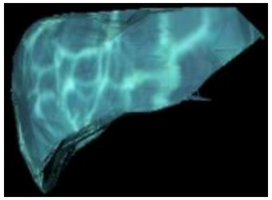
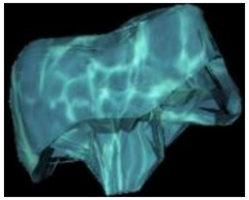
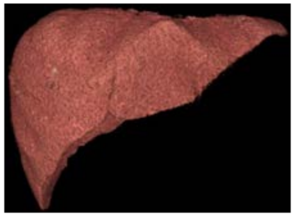
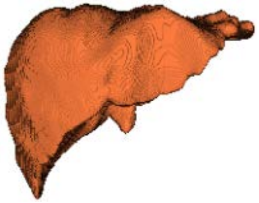
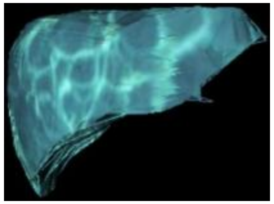
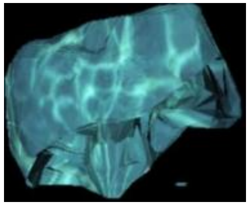
- Performance: **Hybrid** > 2D Auto > 3D Auto

◌ False positive
◌ False negative

Manual (Reference)				
Hybrid				
2D Auto				
3D Auto				

Performance Comparison: Visual Inspection

- Performance: **Hybrid** > 2D Auto > 3D Auto

		Manual (Reference)	**Hybrid**	**OsiriX**	
				2D Auto	3D Auto
1st trial	**3D output**				
	Volume (ml)	(1218.0)	(1221.1)	(1279.6)	(1145.8)
2nd trial	**3D output**				
	Volume (ml)	(1234.0)	(1232.9)	(1278.8)	(1168.5)

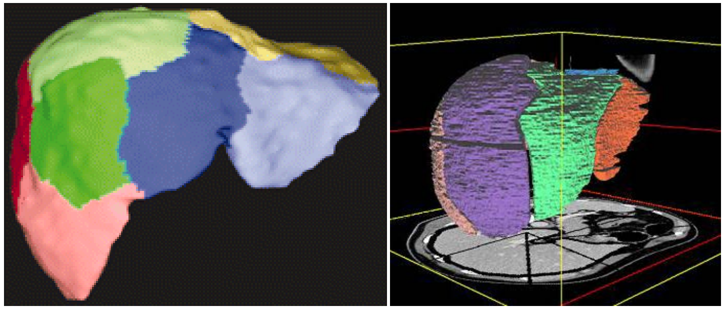
Performance Comparison: Objective Measures

- **Accuracy**: **Hybrid** > 2D Auto & Editing ~ 3D Auto & Editing
- **Reliability**: **Hybrid ≅ 2D Auto & Editing** > 3D Auto & Editing
- **Efficiency**: **Hybrid** > 3D Auto & Editing > 2D Auto & Editing

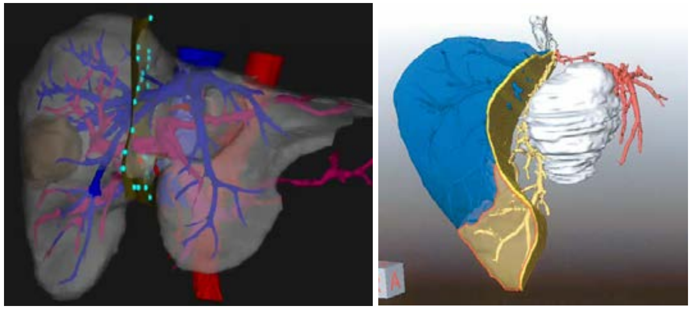
Method		**Liver volume (ml)**		**Time (sec)**	
		SD	**Difference***	**Mean**	**SD**
Hybrid		**4.2**	**8.9**	**261.3**	**35**
OsiriX	2D Auto & Editing	5.9	31.5	1918	162.7
	3D Auto & Editing	15.5	28.7	1796	88

Future Work

- **Interactive segmentation**
  - ✓ More functional
  - ✓ More interactive w/ surgeon



- **Deformable cutting plane**
  - ✓ More flexible
  - ✓ More adaptive to segmentation



- **Clinical application & usability testing**
  - ✓ Efficient
  - ✓ Effective
  - ✓ Satisfactory

Virtual Liver Surgery System 만족도 평가

Q & A

Thank you for your attention!