

SIR-Spheres®
(Yttrium-90 Microspheres)

1. DESCRIPTION

SIR-Spheres® consists of biocompatible microspheres containing yttrium-90 with a size between 20 and 40 microns in diameter. Yttrium-90 is a high-energy pure beta-emitting isotope with no primary gamma emission. The maximum energy of the beta particles is 2.27MeV with a mean of 0.93MeV. The maximum range of emissions in tissue is 11mm with a mean of 2.5mm. The half-life is 64.1 hours. In therapeutic use, requiring the isotope to decay to infinity, 94% of the radiation is delivered in 11 days. The average number of particles implanted is $30 - 60 \times 10^6$. SIR-Spheres® is a permanent implant.

SIR-Spheres® is implanted into a hepatic tumor by injection into either the common hepatic artery or the right or left hepatic artery via the chemotherapy catheter port. The SIR-Spheres® distributes non-uniformly in the liver, primarily due to the unique physiological characteristics of the hepatic arterial flow, the tumor to normal liver ratio of the tissue vascularity, and the size of the tumor. The tumor usually gets higher density per unit distribution of SIR-Spheres® than the normal liver. The density of SIR-Spheres® in the tumor can be as high as 5 to 6 times of the normal liver tissue. Once SIR-Spheres® is implanted into the liver, it is not metabolized or excreted and it stays permanently in the liver.

2. INDICATIONS FOR USE

SIR-Spheres® is indicated for the treatment of unresectable metastatic liver tumors from primary colorectal cancer with adjuvant intra-hepatic artery chemotherapy (IHAC) of FUdR (Floxuridine).

3. CONTRAINDICATIONS

SIR-Spheres® is contraindicated in patients who have

- had previous external beam radiation therapy to the liver,
- ascites or are in clinical liver failure,
- markedly abnormal synthetic and excretory liver function tests (LFTs),
- greater than 20% lung shunting of the hepatic artery blood flow determined by Technetium MAA scan,
- pre-assessment angiogram that demonstrates abnormal vascular anatomy that would result in significant reflux of hepatic arterial blood to the stomach, pancreas or bowel,
- disseminated extra-hepatic malignant disease,
- been treated with capecitabine within the two previous months, or who will be treated with capecitabine at any time following treatment with SIR-Spheres®,
- portal vein thrombosis.

4. WARNINGS

- Inadvertent delivery of SIR-Spheres[®] to the gastrointestinal tract or pancreas will cause acute abdominal pain, acute pancreatitis or peptic ulceration.
- High levels of implanted radiation and/or excessive shunting to the lung may lead to radiation pneumonitis.
- Excessive radiation to the normal liver parenchyma may result in radiation hepatitis.

5. PRECAUTIONS

- No studies have been done on the safety and effectiveness of this device in pregnant women, nursing mothers or children.
- Due to the radioactivity of this device and the significant consequences of misplacing the microspheres in situ, this product must be implanted by doctors with adequate training in the handling and implantation technique for this device.
- Sirtex Medical Inc recommends a SPECT scan of the upper abdomen be performed immediately after implantation of SIR-Spheres[®]. The SPECT scan will detect the Bremsstrahlung radiation from the yttrium-90 to confirm placement of the microspheres in the liver.
- This product is radioactive. The use of this device is regulated under Title 10 of the Code of Federal Regulations Part 35. These regulations must be followed when handling this device.
- All persons handling, dispensing and implanting this device must be familiar with and abide by all Local, State and Federal regulatory requirements governing therapeutic radioactive materials. Accepted radiation protection techniques should be used to protect staff when handling both the isotope and the patient.
- Some patients may experience gastric problems following treatment but H-2 blocking agents may be used the day before implantation of SIR-Spheres[®] and continued as needed to reduce gastric complications.
- Many patients may experience abdominal pain immediately after administration of SIR-Spheres[®] and pain relief may be required.
- SIR-Spheres[®] demonstrated a mild sensitization potential when tested dermally in an animal model.

6. CLINICAL TRIAL RESULTS

In a randomized, controlled clinical trial, a total of 70 patients were studied in two arms, 34 patients with FUDR chemotherapy (control group), and 36 patients with FUDR plus SIR-Spheres[®]. The results are shown in the following tables.

Table 1. Tumor response by volume

Response	CR	PR	NC	PD	Others
FUDR only (N = 34)	1	7	12	9	5
FUDR plus SIR-Spheres [®] (N = 36)*	2	16	10	5	3

* (P=0.033)

Tumor response was measured by two consecutive CT scans in a 3-month interval period.
 CR = Complete Response, PR = Partial Response, NC = No Change, PD = Progressive Disease
 Others = No follow up, or unmeasurable

Table 1 indicates that there is a statistically significant improvement of the tumor response rates (CR+PR) in the group treated with FUDR plus SIR-Spheres[®], when compared with the group treated with FUDR only.

Table 2. Time to first progressive disease in the liver

	FUDR Only	FUDR plus SIR-Spheres[®]
Number of Patients	34	36
Mean Time in Days +/- SD*	312 Days +/- 330	510 Days +/- 516
Median Time in Days*	233 Days	366 Days

* (P=0.05)

Progressive Disease was defined as more than 25 % increase of tumor volume, or development of new lesion(s) in the follow up CT scan, when compared to the pre-treatment CT scan.

Table 2 indicates that there is a statistically significant delay of time to progression of the disease in the group treated with FUDR plus SIR-Spheres[®], when compared with the group treated with FUDR only.

7. ADVERSE EVENTS

When the patient is treated with proper technique, without excessive radiation to any organ, the common adverse events after receiving the SIR-Spheres[®] are fever, transient decrease of hemoglobin, mild to moderate abnormality of liver function tests (mild increase in SGOT, alkaline phosphatase, bilirubin), abdominal pain, nausea, vomiting, and diarrhea.

In the phase III randomized controlled clinical trial with 70 patients, there was a minimal increase of Grade 1 and 2 events, mostly transient abnormal LFTs and nausea and vomiting in the patients who received SIR-Spheres[®]. There was no difference in the number of patients who developed Grade 3 and 4 adverse events between the two groups. No patient died due to the adverse events directly related to SIR-Spheres[®].

Table 3. Adverse Events

	Grade 1 and 2		Grade 3 and 4	
Events	FUDR	FUDR + SIR-Spheres[®]	FUDR	FUDR+ SIR-Spheres[®]
Hemoglobin	4	5	1	0
Bilirubin	7	2	0	1
AST (SGOT)	110	109	14	7
Alk. Phos.	90	188	5	14
Nausea/vomiting	5	13	2	1
Diarrhea	6	3	1	0
Total	222	320	23	23

The data are from a clinical trial with 34 patients on chemotherapy only, and 36 patients on chemotherapy plus SIR-Spheres[®].

Potential serious adverse events due to high radiation:

- **Acute pancreatitis** ---- causes immediate severe abdominal pain. Verify by SPECT imaging of the abdomen (Yttrium-90 Bremsstrahlung image) and test for serum amylase.
- **Radiation Pneumonitis** ---- causes excessive nonproductive cough. Verify by X-ray evidence of pneumonia.
- **Acute Gastritis** ---- causes abdominal pain. Verify by standard methods to diagnosis gastric ulceration.
- **Radiation Hepatitis** ---- causes unexplained progressive deterioration of liver function. Verify by transcutaneous core biopsy of the liver.

8. PATIENT SELECTION and PRETREATMENT TESTING

- Patients are indicated for treatment with SIR-Spheres® when the metastatic colorectal cancer in the liver is considered non-resectable. In any of the following circumstances, patients would generally be considered non-resectable:
 1. multiple liver metastases together with involvement of both lobes;
 2. tumor invasion of the hepatic confluence where the three hepatic veins enter the IVC such that none of the hepatic veins could be preserved if the metastases were resected;
 3. tumor invasion of the porta hepatis such that neither origin of the right or left portal veins could be preserved if resection were undertaken; and
 4. widespread metastases such that resection would require removal of more liver than is necessary to maintain life.
- Resectability may be evaluated via imaging with a triple phase contrast angio-portal CAT scan or MRI.

Patient Tests Before Treatment with SIR-Spheres®

The following tests are recommended before treatment.

- A hepatic angiogram should be performed to establish arterial anatomy of the liver.
- A nuclear medicine break-through scan (Intrahepatic Technetium MAA Scan) to determine the percent lung shunting. If a port has been inserted, this test can be performed through the port.
- Serologic tests of liver function should be performed to determine the extent of liver function damage.

Appropriate imaging studies are recommended to determine the extent of disease. These may include chest x-ray, CT scan of chest and abdomen, abdominal ultrasound and a bone scan.

9. RADIATION SAFETY

The preparation and implant procedure must be regarded as being a potentially serious radiation hazard to the staff and a serious contamination hazard. Regulatory and local radiation usage guidelines should be followed concerning implantation and post-implantation care.

The following are sample measured thermoluminescent dosimetry (TLD) exposures to personnel.

Table 4. Exposure dose per patient for implant preparation (Technologist)

	Trunk mSv (mrem)	Lens of the eye MSv (mrem)	Hands mSv (mrem)

Shallow dose (0.07 mm)	0.027 (2.7)	0.026 (2.6)	0.35 (35)
Deep dose (10 mm)	0.003 (0.3)	0.004 (0.4)	

Assuming handling of a 3 GBq device and dose preparation time of 30 minutes. TLDs were worn near the pelvis, on the shirt's lapel, and on the working finger.

Table 5. Exposure dose per patient for implant procedure (Physician)

	Trunk mSv (mrem)	Lens of the eye mSv (mrem)	Hands mSv (mrem)
Shallow Dose (0.07mm)	0.038 (3.8)	0.12 (12)	0.32 (32)
Deep Dose (10 mm)	0.004 (0.4)	0.054 (5.4)	

Assuming average patient dose of approximately 2 GBq and dose injection time of 20 minutes.

Post-Implant Exposure

Exposure data from patients implanted with an average of 2.1GBq at approximately 5-6 hours post implantation at the following distances from the patient's abdomen:

0.25m	18.8 μ Sv/hr
0.5m	9.2 μ Sv/hr
1m	1.5 μ Sv/hr
2m	0.4 μ Sv/hr
4m	<0.1 μ Sv/hr
(1 mSv= 100 mrem)	

10. HOW SUPPLIED

SIR-Spheres[®] is provided in a vial with water for injection. Each vial contains 3 GBq of yttrium-90 (at the time of calibration) in a total of 5 cc water for injection. Each vial contains 40 – 80 million microspheres. The vial is shipped within a 6.4mm thick, lead pot. The package consists of a crimp sealed SIR-Spheres[®] glass vial within a lead pot, and a package insert within Type A packing bucket.

The vial and its contents should be stored inside its transportation container at room temperature (15-25° C, 59-77° F).

The calibration date (for radioactive contents) and the expiration information are quoted on the vial label. The useful life of the SIR-Spheres[®] is 24 hours from the time of calibration. The particle size has been validated before shipment, as 32.5 μ +/- 2.5 μ . Less than 10% will be > 30 μ and < 35 μ .

Appendices

- I. General Information**
- II. Dose Preparation Procedure**
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- IV. Radiation Dosimetry**
- V. Technique for Performing the Intra-hepatic Technetium MAA Scan**
- VI. Correction for Decay**

Appendix I

GENERAL INFORMATION

Restricted to Accredited Facilities

SIR-Spheres[®] may only be dispatched to a duly licensed or accredited facility capable of handling therapeutic medical isotopes.

Restricted to Licensed Physicians

Only doctors qualified and licensed under Title 10 Code of Federal Regulations Part 35 (Nuclear Regulatory Commission) may order and implant SIR-Spheres[®].

Appendix II

Dose Preparation Procedure:

- Unpack SIR-Spheres[®], leaving shipping vial lead pot and place on the bench top lead shielded box. As an option, you can place the lead pot behind your own lead-shielded glass, if you have one.
 - Remove the center of aluminum seal from sterile glass v-vial with forceps, and clean the rubber top with alcohol swap.
 - Place the glass v-vial in an empty lead pot (10 cm x 6 cm) for stability and shielding.
 - Open the shipping vial lead pot; remove the SIR-Spheres[®] shipping vial.
 - Using a qualified dose calibrator, calibrate the activity in the shipping vial to current time and record the activity. Use the Table 1., Decay Factor Chart, or accompanying decay graph. Make sure the pre-shipment calibration time zone is converted to current local time zone.
 - Remove partially the aluminum seal of the SIR-Spheres[®] delivery vial, clean with alcohol swap.
 - Draw 2 mL room air into a shielded 5 mL syringe attached with a 20 gauge Huber point needle, and puncture through the rubber top of the SIR-Spheres[®] delivery vial, and quickly draw back and forth several times in order to mix the SIR-Spheres[®] thoroughly.
 - Lay lead pot containing the SIR-Spheres[®] vial at approximately 45° angle, withdraw quickly a pre-calculated specific amount of patient dose, and transfer into the glass-v vial in the other lead pot. Make sure to withdraw the required amount quickly, before the content of the shipping vial starts to settle.
 - Verify the patient dose in the glass-v vial by re-measuring the activity in the shipping vial with dose calibrator, and correct, if necessary.
 - Put the glass-v vial, containing the confirmed patient dose into the dedicated Perspex shield.
- Now, the patient dose is ready for transport to the SIR-Spheres[®] implantation room.

Appendix III

CALCULATION OF INDIVIDUAL DOSE

There are generally two acceptable methods in calculating the individual patient dose; the partition model (individual dose calculation), and empirical model. The empirical model accepts the safety margins of the dose known from the previously published clinical data and chooses the most safe and effective dose from it. The empirical model has been used in the pivotal clinical trial of the SIR-Spheres®.

The patient dose can be determined according to the following table 1.

Table 1. The Recommended Patient Dose

The % involvement by the tumor in the liver	Recommended Y-90 Dose*
> 50 %	3.0 GBq
25 % - 50 %	2.5 GBq
< 25 %	2.0 GBq

CAUTION: The recommended implanted activities are specific to SIR-Spheres®. They are not applicable and should not be extrapolated to other implanted Y-90 sources.

* When there is 10 % or more lung shunting, the patient dose would be further reduced, according to the following table 2.

Table 2. Dose Reduction Factors for Patients with Lung Shunting

% Lung shunting	Reduction Factor
< 10 %	No reduction
10 % - 15 %	20 % reduction
15 % - 20 %	40 % reduction
> 20 %	No Treatment

Lung Shunt Calculation Procedure:

- Inject 4 mCi (150MBq) of Tc-99m MAA into the hepatic artery via a port or catheter
- Use a large FOV gamma camera, and obtain anterior and posterior images of the chest and abdomen (with 700k to 1 million counts on abdomen, and the same count on the chest),
- Take right lateral abdomen, using same count,
- Draw ROI around the whole liver and the whole lung and get the total counts for the lung and the liver,
- Calculate the % shunt using following formula:

$$\% \text{ Shunt} = (\text{Lung Counts} / \text{Liver Counts} + \text{Lung Counts}) \times 100$$

Appendix IV

RADIATION DOSIMETRY

The radiation dosimetry of the SIR-Spheres[®] can be a complex and difficult task due to the non-uniform distribution of the particles in the normal liver and the tumors. In general, 1 GBq (27 mCi) of Yttrium-90/kg of tissue provides 50 Gy of radiation dose.* However, because of the non-uniform distribution of the dose between the tumor and the normal liver tissue, a proportionally larger amount of radiation will be delivered to the tumor tissue, and less amount to the liver.

* Russell, Carden, Herron: 'Dosimetry Calculations of Yttrium-90 used in the treatment of liver cancer.' *Endocurietherapy/Hypertherm Oncol.* 1988;4:171-186

In example, a patient, who has a liver weighing 1500 g, and has two tumor nodules, A 4 cm size tumor in the right lobe, and a 3 cm size nodule in the left lobe. The post-injection images suggest that there is 5:1 density ratio for unit volume between the tumor and the liver. The patient received 2 GBq of SIR-Spheres[®]. In such case, the calculated radiation dose to the tumor is 294 Gy and the dose to the liver tissue is 58.5 Gy.

The radiation dose for other organs would be minimal or negligible, except for the organs adjacent to the liver, such as the stomach, large intestine, gall bladder, and the lung. The radiation dose may increase significantly, when there is a shunting of the arterial blood to the lung, stomach, or small intestine.

Appendix V

Technique for Performing the Intra-hepatic Technetium MAA Scan

Purpose:	To assess arterial perfusion of the liver and the fraction of radiopharmaceutical tracer that will pass through the liver and lodge in the lungs.
Agent:	Technetium-99 labeled MAA (Macro-Aggregated Albumin)
Dose:	150MBq (4 mCi)
Equipment:	Any large FOV gamma camera
Administration:	The patient needs to have a surgically implanted port or trans-femoral catheter placed in the hepatic artery. The Technitium-99 labeled MAA is injected into the port or catheter.
Imaging:	The patient is positioned supine under the gamma camera and the images recorded. * Anterior and posterior images of abdomen and thorax. Collect 700k –1000k cts for abdomen and same time for thorax * Right lateral abdomen - same time acquisition as for anterior
Analysis:	Draw ROI around whole of liver and whole of lung fields. Calculate G mean for liver region and lung region. Calculate Lung/Liver ratio using the following formula. $\% \text{ lung shunting} = (\text{counts of total lung} / \text{counts of total lung plus counts of liver}) \times 100$
Interpretation:	If percent lung shunting is >10% then there is need for dose reduction of SIR-Spheres [®] (see <i>Table 1</i> below)

Table 1. Dose Reduction Recommendations

Percent Lung Shunting	Activity of SIR-Spheres [®]
< 10%	Deliver full amount of SIR-Spheres [®]
10% to 15%	Reduce amount of SIR-Spheres [®] by 20%
15% to 20%	Reduce amount of SIR-Spheres [®] by 40%
> 20 %	Do not give SIR-Spheres [®]

Appendix VI

CORRECTION FOR DECAY

The physical half-life of yttrium-90 is 64.1 hours. Radioactive decay factors should be applied at the time of patient dose preparation, in order to calculate the true value of radioactivity present.

Table 1. Decay Factors of Yttrium-90 Sir-Spheres

Hours	Decay Factor
0.5	0.995
1	0.989
2	0.979
3	0.968
4	0.956
5	0.947
6	0.937
7	0.927
8	0.917
9	0.907
10	0.898
11	0.888
12	0.878
24	0.772
36	0.678
48	0.595
72	0.459

* Caution: The time of the initial calibration must be converted to the user's local time.