Incisional Corneal Refractive Surgery

Refractive Surgery

Intraocular
- Pseudophakic
  - Refractive lens exchange (RLE)
- Phakic IOL
  - Iris-fixated
  - Sulcus-fixated

Corneal
- Incisional
- Laser
  - PRK
  - LASEK
  - Epi-LASIK
  - LASIK
  - SMILE
- Other
  - CK
  - SAI
  - CRI
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  - ICRS
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What does RK stand for? What does AK stand for? What does LRI stand for?
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What does RK stand for? Radial Keratotomy
What does AK stand for? Arcuate Keratotomy
What does LRI stand for? Limbal Relaxing Incisions
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Pseudophakic

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Incisional

Laser

Other

Incisional Corneal Refractive Surgery

What is the fundamental difference between RK vs AK/LRI (other than that RK is no longer performed)?

RK

AK

LRI

PRK

LASEK

Epi-LASIK

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CK

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Briefly, how is RK performed?

Radial incisions are made that extend from the peripheral cornea to the edge of the 'optical zone' (central portion of the cornea bounded by a 3-4 mm diameter ring). How deep are these cuts made? Quite deep—about 85-90% corneal thickness. How many cuts are made? Usually 4 or 8, occasionally 16, hopefully not 32 (although it's been done, unfortunately). How do radial cuts correct myopia? The radial cuts gape, causing the peripheral cornea to bulge. This steepens the peripheral cornea, which in turn flattens the central cornea. Essentially, RK works by redistributing corneal power from the central cornea to the peripheral cornea.
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This is why RK can’t be used to treat hyperopia. Recall that hyperopes need added plus power to correct their refractive error. Thus, hyperopic keratorefractive surgery must steepen the central cornea in order to add plus power. However, incising the cornea (ie, RK) can only flatten it—so no RK for hyperopes.

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Steepening of the peripheral cornea leads inevitably to an increase in which higher-order aberration?

This steepens the peripheral cornea.

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- **Intraocular**
  - Pseudophakic
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Spherical aberration

This steepens the peripheral cornea.
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The native, normal cornea is steeper centrally than it is peripherally. What is the term for this shape?

Prolate

After RK (and other myopic keratorefractive procedures), this relationship is often reversed; ie, the central cornea is flatter than the peripheral cornea. What is the term for this shape?

Oblate
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How much steeper (in diopters) is the typical central cornea than the typical peripheral cornea?
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Incisional Corneal Refractive Surgery

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In two words, what is the main short-term problem with RK?
'Diurnal fluctuation.'

What does this refer to?
To the fact that a significant proportion of RK eyes are more hyperopic upon awakening in the morning.

Is this hyperopic shift permanent?
No. As the day proceeds, the extra hyperopia 'wears off,' and the eye reverts to its previous state.

What accounts for diurnal fluctuation?
Hypoxic edema. Closed eyelids during sleep deprive the cornea of O2, and the resulting hypoxia causes the incisions to swell a little. This swelling in turn induces increased flattening of the central cornea, resulting in more hyperopia. After several hours of O2 exposure while the eyes are open, the edema dissipates, and the excess hyperopia resolves.
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**What does this refer to?**

In the context of Radial Keratotomy (RK), diurnal fluctuation refers to the temporary hyperopic shift that occurs after RK surgery. This phenomenon is characterized by increased hyperopia in the early morning hours, which gradually improves throughout the day as the eye returns to its pre-surgery state. The shift is attributed to hypoxic edema, where closed eyelids during sleep deprive the cornea of oxygen, leading to incision swelling and increased flattening of the central cornea. This swelling induces the hyperopic effect. As oxygen levels increase during the day, the swelling resolves, and the eye returns to its baseline state.
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Refractive Surgery

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Corneal

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Radial incisions are made that extend from the peripheral cornea to the edge of the ‘optical zone’ (central portion of the cornea bounded by a 3-4 mm diameter ring).

**In two words, what is the main long-term problem with RK?**
Hyperopic drift

The radial cuts gape, causing the peripheral cornea to bulge. This steepens the peripheral cornea, which in turn flattens the central cornea. *Essentially, RK works by redistributing corneal power from the central cornea to the peripheral cornea.*
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Refractive Surgery

Corneal

Intraocular

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IncisionalRK

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In two words, what is the main long-term problem with RK?
‘Hyperopic drift’

(Note: ‘Hyperopic drift’ is aka progressive flattening effect of surgery)
Incisional Corneal Refractive Surgery

**Refractive Surgery**

- **Incisional**
  - Pseudophakic
  - Phakic IOL
  - Incisional Corneal Refractive Surgery
    - PRK
    - LASEK
    - CK
    - ICRS
    - CXL
    - LASIK
    - SMILE
    - Epi-LASIK
    - RK
    - AK
    - LRI

**Intraocular**

- Pseudophakic
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**Corneal**

- Laser
- Laser (PRK)
- Other
- CK

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‘Hyperopic drift’

**What does this refer to?**
To the fact that a significant proportion of RK eyes gradually become more and more hyperopic over time.

**According to the Prospective Evaluation of Radial Keratotomy (PERK) study, what percentage of RK eyes will manifest a diopter or more of hyperopic drift after 10 years?**
Just over 40!
**Incisional Corneal Refractive Surgery**

**Refractive Surgery**

- **Intraocular**
  - Pseudophakic
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Hyperopic drift

**What does this refer to?**
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Refractive surgery

Incisional Corneal Refractive Surgery

Intraocular

- Pseudophakic
  - Refractive lens exchange (RLE)
- Phakic IOL

Corneal

- Incisional
  - RK
- Laser
  - PRK
- Other
  - CK

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According to the Prospective Evaluation of Radial Keratotomy (PERK) study, what percentage of RK eyes will manifest a diopter or more of hyperopic drift after 10 years?
Just over 40!
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Quitting smoking within 6 months?
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Incisional Corneal Refractive Surgery

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Is there anything that can be done to reduce the likelihood of a hyperopic refractive surprise?

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First, determine corneal power by either 1) measuring it directly (via a technology capable of doing so in a post-RK eye); 2) using keratometric measurements obtained pre-RK (usually difficult or impossible to obtain); or 3) performing a hard contact-lens overrefraction; then

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Is there anything that can be done to reduce the likelihood of a hyperopic refractive surprise?

Yes. A number of alternative IOL power calculation techniques have been developed (see the IOL Calculations slide-set for details). The short version is as follows:

First, determine corneal power by either 1) measuring it directly (via a technology capable of doing so in a post-RK eye); 2) using keratometric measurements obtained pre-RK (usually difficult or impossible to obtain); or 3) performing a hard contact-lens overrefraction; then Second, performing the calcs via several of the 3rd or 4th generation calc formula, then using the highest IOL power that pops out of those calcs

What does this refer to?

To the fact that a significant proportion of RK eyes gradually become more and more hyperopic over time.

Usually quite!

According to the Prospective Evaluation of Radial Keratotomy (PERK) study, what percentage of RK eyes will manifest a diopter or more of hyperopic drift after 10 years?

Over 40!

In two words, what is the main long-term problem with RK?

Hyperopic drift

What does this refer to?

To the fact that a significant proportion of RK eyes gradually become more and more hyperopic over time.

Essentially, RK works by redistributing corneal power from the central cornea to the peripheral cornea.
Incisional Corneal Refractive Surgery

Refractive Surgery

What is the other main problem associated with RK? (Hint: It’s not usually encountered until the pt is 60+ years old.)

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If standard IOL calc techniques are applied to an RK eye, will the resulting ‘refractive surprise’ be myopic, or hyperopic?

Hyperopic

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With regard to the IOL itself, can a toric and/or a multifocal lens be used in a post RK eye?

A toric lens can be considered, but multifocals should be avoided in these eyes.

Briefly, how is RK performed?

Radial incisions are made that extend from the peripheral cornea to the edge of the ‘optical zone’ (central portion of the cornea bounded by a 3-4 mm diameter ring)

How deep are these cuts made?

Quite deep—about 85-90% corneal thickness

How many cuts are made?

Usually 4 or 8, occasionally 16, hopefully not 32 (although it’s been done, unfortunately)

How do radial cuts correct myopia?

The radial cuts gape, causing the peripheral cornea to bulge. This steepens the peripheral cornea, which in turn flattens the central cornea. Essentially, RK works by redistributing corneal power from the central cornea to the peripheral cornea.
Incisional Corneal Refractive Surgery

Refractive Surgery

Corneal Incisional Laser Surgery

Iris-fixated Intraocular Pseudophakic Phakic IOL Sulcus-fixated Refractive lens exchange (RLE)

Other Incisional Corneal Refractive Surgery

PRK
LASEK
CK
ICRS
CXL
LASIK
SMILE
Epi-LASIK
RK
AK
LRI

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If standard IOL calculation techniques are applied to a post-RK eye, will the resulting 'refractive surprise' be myopic, or hyperopic?
Hyperopic

In two words, what is the main long-term problem with RK?
"Hyperopic drift"

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Incisional Corneal Refractive Surgery

Refractive Surgery

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If the RK cornea possesses significant astigmatism, where should the cataract incision be placed?
If feasible, on the steep meridian other
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Refractive Surgery

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If RK cornea is flat vs steep

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Incisional Corneal Refractive Surgery

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Incisional Corneal Refractive Surgery

Refractive Surgery

Incisional Corneal Refractive Surgery

PRK
LASEK
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ICRS
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SMILE
Epi-LASIK
RK
AK
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In two words, what is the main short-term problem with RK?
'Diurnal fluctuation'

What does this refer to?
To the fact that a significant proportion of RK eyes are more hyperopic upon awakening in the morning.

Is this hyperopic shift permanent?
No. As the day proceeds, the extra hyperopia 'wears off,' and the eye reverts to its previous state.

What accounts for diurnal fluctuation?
Hypoxic edema. Closed eyelids during sleep deprive the cornea of O2, and the resulting hypoxia causes the incisions to swell a little. This swelling in turn induces increased flattening of the central cornea, resulting in more hyperopia. After several hours of increased O2 exposure while the eyes are open, the edema dissipates, and the excess hyperopia resolves.

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If standard IOL calc techniques are applied to an RK eye, will the resulting 'refractive surprise' be myopic, or hyperopic? Hyperopic

Because of these (and other) issues, RK is considered 'obsolete,' and thus is no longer performed in the US.
There is another procedure, similar to AK and LRI, that was at one time commonly used to correct astigmatism, but is rarely used today. What is it?
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(Note: ‘Transverse keratotomy’ is aka tangential keratotomy)
There is another procedure, similar to AK and LRI, that was at one time commonly used to correct astigmatism, but is rarely used today. What is it? **Transverse keratotomy**

In what fundamental way does transverse keratotomy differ from AK and LRI?
Refractive Surgery

Incisional Corneal Refractive Surgery

Intraocular

Pseudophakic

Phakic IOL

Corneal

Incisional

Laser

Other

PRK

LASEK

Epi-LASIK

LASIK

SMILE

RK

AK

LRI

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Transverse keratotomy

In what fundamental way does transverse keratotomy differ from AK and LRI?

In terms of the shape of the incision—AK/LRI incisions are curved whereas transverse keratotomy incisions are straight.
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In what fundamental way does AK differ from LRI?

AK incisions are made ~7 mm from the center of the cornea, whereas LRI incisions are made at the limbus.
In what fundamental way does AK differ from LRI? In terms of the location of the incision--AK incisions are made ~3.5 mm from the center of the cornea, whereas LRI incisions are made at the location.
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Incisional Corneal Refractive Surgery

Are AK and LRI incisions placed on the steep, or the flat meridian of the cornea?

Corneal

Laser

- PRK
- LASEK
- Epi-LASIK
- LASIK
- SMILE

Other

- CK
- SAI
- CRI
- CXL
- ICRS
Incisional Corneal Refractive Surgery

**Corneal**

- Incisional
  - RK
  - AK
  - LRI

- Laser
  - PRK
  - LASEK
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  - SMILE

- Other
  - CK
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Are AK and LRI incisions placed on the steep, or the flat meridian of the cornea?
The steep
Incisional Corneal Refractive Surgery

Are AK and LRI incisions placed on the steep, or the flat meridian of the cornea? The steep

Are they performed singularly, or in pairs?

In pairs, on opposite sides of the cornea

Which is more commonly used today? LRIs, by a mile

What is the typical context in which LRIs are used? They are usually performed at the time of cataract surgery, or shortly thereafter

What is the typical context in which AKs are used? To correct post-penetrating keratoplasty astigmatism
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Incisional
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- CK
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- CRI
- CXL
- ICRS
Are AK and LRI incisions placed on the steep, or the flat meridian of the cornea?
The steep

Are they performed singularly, or in pairs?
In pairs, on opposite sides of the cornea

Which is more commonly used today?
LRI, by a mile
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Which is more commonly used today?
LRIs, by a mile

What is the typical context in which LRIs are used?

They are usually performed at the time of cataract surgery, or shortly thereafter
Incisional Corneal Refractive Surgery

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Incisional Corneal Refractive Surgery

Refractive Surgery

Corneal

Incisional

Laser

Other

PRK

SAI

CRI

CXL

ICRS

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Which is more commonly used today?
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What is the typical context in which LRIs are used?
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What is the typical context in which AKs are used?
To correct post-astigmatism common eye surgery
Incisional Corneal Refractive Surgery

Refractive Surgery

Corneal

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Incisional

Laser

Other

RK

AK

LRI

PRK

LASEK

Epi-LASIK

LASIK

SMILE

CK

SAI

CRI

CXL

ICRS
Incisional Corneal Refractive Surgery

Refractive Surgery

Corneal

Incisional

- RK
- AK
- LRI

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In treating post-PK astigmatism, where are the AK incisions placed?
Incisional Corneal Refractive Surgery

Refractive Surgery

Corneal

Incisional

Laser

Other

PRK
LASEK
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LASIK
CK
SAI
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CXL
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They are usually performed at the time of cataract surgery, or shortly thereafter

What is the typical context in which AKs are used?
To correct post-penetrating keratoplasty astigmatism

In treating post-PK astigmatism, where are the AK incisions placed?
Either in the host vs donor cornea, or the PK incision itself
Incisional Corneal Refractive Surgery

Refractive Surgery

Corneal

Incisional

Laser

Other

- RK
- AK
- LRI

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Why not place the incisions in the host bed?
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Either in the donor cornea, or the PK incision itself

Why not place the incisions in the host bed?
Because doing so produces only a negligible effect on the astigmatism
Incisional Corneal Refractive Surgery

What was the typical context in which transverse keratotomy was used?

Transverse keratotomy
Incisional Corneal Refractive Surgery

Refractive Surgery

Intraocular

Pseudophakic

Phakic IOL

Corneal

Incisional

Laser

Other

RK

AK

LRI

PRK

LASEK

Epi-LASIK

LASIK

SMILE

CK

SAI

CRI

CXL

ICRS

Transverse keratotomy

What was the typical context in which transverse keratotomy was used?

It was used in conjunction with RK to correct the astigmatic portion of the RK pt’s refractive error. As RK fell out of favor, transverse keratotomy fell with it.
Incisional Corneal Refractive Surgery

When AK and LRI incisions placed on the steep meridian of the cornea, what effect do they have on that meridian’s steepness?

They flatten it.

What effect (if any) does placement of AK or LRI incisions have on the steepness of the meridian 90 degrees away (ie, the opposite meridian)?

They steepen it.

What is the name for the phenomenon of incisions producing steepening in the opposite meridian?

Coupling

In this context, what is the coupling ratio?

It is an index of the relative flattening and steepening caused by the incisions. It is defined as the amount of flattening (in diopters) divided by the amount of steepening (again, in diopters).

What is the effect of the incisions on the spherical equivalent (SE) of the eye if the coupling ratio is…

> 1? There is a hyperopic shift.

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Incisional Corneal Refractive Surgery

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They steepen it.

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Coupling.

In this context, what is the coupling ratio?

When the coupling ratio is greater than 1, there is a hyperopic shift. When the coupling ratio is less than 1, there is a myopic shift. When the coupling ratio is 1, the spherical equivalent of the eye remains unchanged.
Incisional Corneal Refractive Surgery

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What is the most important factor in determining the coupling ratio of an AK/LRI procedure?

The procedure itself. Specifically, the LRI procedure essentially always produces a ratio of 1.0, whereas results with the AK procedure are more variable.
Incisional Corneal Refractive Surgery

<table>
<thead>
<tr>
<th>Procedure</th>
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</tr>
</thead>
<tbody>
<tr>
<td>PRK</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
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With respect to AK, what factors influence the coupling ratio? -- -- --
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With respect to AK, what factors influence the coupling ratio?

--The length of the incisions

--The depth of the incisions

--The size of the optical axis
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--The length of the incisions
--The depth of the incisions
--The size of the optical zone
Incisional Corneal Refractive Surgery

With regard to AKs and LRIs, what factors influence their effectiveness?
-- Pt age
-- The number of incisions
-- The length of the incisions
-- The depth of the incisions

Should incisional correction of astigmatism be based on a manifest refraction, or corneal topography?
It depends. AKs performed as a stand-alone procedure should be based on the manifest refraction, so as to offset both corneal and lenticular astigmatism. In contrast, LRIs performed at the time of cataract surgery should be based on corneal topography, because any astigmatism owing to the lens will be dealt with by the CE surgery.

When marking the pt's eye prior to making the incisions, what should you have the pt do?
Sit up
Why? In a word, cyclotorsion. When a pt lies down, their eyes rotate up to 15°. Thus, assuming the pt was refracted/had topography performed while seated, incisions based on the position of the eye while the pt is supine will be off by up to 15°.
With regard to AKs and LRIs, what factors influence their effectiveness?

- Patient age
- The number of incisions
- The length of the incisions
- The depth of the incisions

Incisional Corneal Refractive Surgery

- Incisional Corneal Refractive Surgery
  - RK
  - AK
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