



CyberKnife® Robotic Radiosurgery System

Radiosurgery System Comparisons

Radiosurgery and Radiotherapy



	Radiosurgery	Radiotherapy
Average Dose Per Fraction	High dose (~ 6 to 25 Gy per fraction)	Low dose (~ 2 Gy per fraction)
Typical # of Fractions	1 – 5 fractions	30 – 45 fractions
Typical # of Unique Beams Per Fraction	150 – 200	5 – 10
Typical Targeting Accuracy	< 1 millimeter	3 – 20 millimeters
Clinical Intent	Tumor ablation	Cumulative dose tumor control

Dose Escalation for Tumor Ablation Necessitates:

Extreme Targeting Accuracy

- Ability to deliver sub-millimeter mechanical accuracy
- Ability to deliver sub-millimeter tumor targeting accuracy

Large Non-Coplanar Beam Delivery

- Ability to diversify beam trajectories to reduce risks of dose toxicity
 - Agility to target tumors from a high volume of unique angles

Radiation Delivery System Comparison



Radiation Therapy Systems	
Targeting Accuracy	5 – 20 millimeters
Applications	Intracranial and Extracranial
Ability to Fractionate	Unlimited
Image Guidance	Typically limited to MV portal imaging on a weekly basis
Non-Coplanar Delivery Capabilities	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations. Patient / gantry collision potential and the impractical nature of manual patient positioning has resulted in little or no clinical adoption
Moving Tumor Targeting	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure
Stereotactic Frames	Immobilization devices used. Low dose per fraction reduces need for accuracy

Varian Clinac®
Elekta Synergy®
Siemens PRIMUS®
TomoTherapy Hi-ART System®

Radiation Delivery System Comparison



	Radiation Therapy Systems	Radiation Therapy Systems Adapted for Radiosurgery
Targeting Accuracy	5 – 20 millimeters	3 – 20 millimeters
Applications	Intracranial and Extracranial	Intracranial and Extracranial
Ability to Fractionate	Unlimited	Unlimited
Image Guidance	Typically limited to MV portal imaging on a weekly basis	Image guidance limited to pre-treatment, patient set-up only <ul style="list-style-type: none"> High resolution kV imaging / cone-beam CT
Non-Coplanar Delivery Capabilities	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations. Patient / gantry collision potential and the impractical nature of manual patient positioning has resulted in little or no clinical adoption 	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations, however without image guidance due to patient / OBI collisions - resulting in less than ideal targeting accuracy. Further, the impractical nature of manual patient positioning has resulted in little or no clinical adoption
Moving Tumor Targeting	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure
Stereotactic Frames	Immobilization devices used. Low dose per fraction reduces need for accuracy	Required in most Intracranial & Extracranial cases

Varian Trilogy™
Elekta Axesse™
BrainLAB Novalis®

Radiation Delivery System Comparison



	Radiation Therapy Systems	Radiation Therapy Systems Adapted for Radiosurgery	Dedicated Cobalt 60 Radiosurgery Systems
Targeting Accuracy	5 – 20 millimeters	3 – 20 millimeters	< 1 millimeter
Applications	Intracranial	<p>Elekta Gamma Knife® Elekta Perfexion™ American Radiosurgery GammaART-6000™</p>	Intracranial only <ul style="list-style-type: none"> Limited spine capabilities (C1 & C2) Perfexion™ only
Ability to Fractionate	Unlimited		Typically limited to a single fraction due to time, resource, and pain constraints
Image Guidance	Typically limited to MV portal imaging on a weekly basis	Image guidance limited to pre-treatment, patient set-up only <ul style="list-style-type: none"> High resolution kV cone-beam CT 	None, relies exclusively on target's fixed relative position to the stereotactic frame <ul style="list-style-type: none"> Frame mechanical accuracy may introduce 1.2-1.9 mm error (*Maciunas)
Non-Coplanar Delivery Capabilities	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations. Patient / gantry collision potential and the impractical nature of manual patient positioning has resulted in little or no clinical adoption 	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations, however without image guidance due to patient / OBI collisions - resulting in less than ideal targeting accuracy. Further, the impractical nature of manual patient positioning has resulted in little or no clinical adoption 	Hemisphere with fixed collimators enables a non-coplanar workspace capable of delivering a maximum of 201 (190 Perfexion™) unique beam angles
Moving Tumor Targeting	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure	N/A
Stereotactic Frames	Immobilization devices used. Low dose per fraction reduces need for accuracy	Required in most Intracranial & Extracranial cases	Requires invasive frames in all cases

* RJ Maciunas, RL Galloway Jr, JW Latimer. The application accuracy of stereotactic frames. *Neurosurgery* 35(4): 682–695, Oct 1994

Radiation Delivery System Comparison



	Radiation Therapy Systems	Radiation Therapy Systems Adapted for Radiosurgery	Dedicated Cobalt 60 Radiosurgery Systems	Dedicated Robotic Radiosurgery Systems
Targeting Accuracy	5 – 20 millimeters	3 – 20 millimeters	< 1 millimeter	< 1 millimeter for stationary tumors < 1.5 millimeters for moving tumors
Applications	Intracranial and Extracranial	Intracranial and Extracranial	<p>Accuray Incorporated CyberKnife® System</p> <ul style="list-style-type: none"> Limited spine capabilities (C1 & C2) Perfexion™ only 	Intracranial and Extracranial
Ability to Fractionate	Unlimited	Unlimited	Typically limited to a single fraction due to time, resource and pain constraints	Unlimited
Image Guidance	Typically limited to MV portal imaging on a weekly basis	Image guidance limited to pre-treatment, patient set-up only <ul style="list-style-type: none"> High resolution kV imaging / cone-beam CT 	None, relies exclusively on target's fixed relative position to the stereotactic frame <ul style="list-style-type: none"> Frame mechanical accuracy may introduce 1.2-1.9 mm error (*Maciunas) 	Continual image guidance throughout the treatment <ul style="list-style-type: none"> High resolution kV imaging Automatically track, detect and correct for tumor and patient movement
Non-Coplanar Delivery Capabilities	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations. Patient / gantry collision potential and the impractical nature of manual patient positioning has resulted in little or no clinical adoption 	Limited clockwise / counter-clockwise gantry mobility enables a single plane typically delivering 7 unique beam angles <ul style="list-style-type: none"> Additional planes can be achieved with manual couch yaw rotations, however without image guidance due to patient / OBI collisions - resulting in less than ideal targeting accuracy. Further, the impractical nature of manual patient positioning has resulted in little or no clinical adoption 	Hemisphere with fixed collimators enables a non-coplanar workspace capable of delivering a maximum of 201 (190 Perfexion™) unique beam angles	Robotic mobility enables a large non-coplanar workspace capable of seamlessly delivering more than 1200 unique beam angles without treatment interruption or the need to manually reposition the patient
Moving Tumor Targeting	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure	Utilizes gating / breath-holding techniques resulting in large contour margins and unnecessary healthy tissue exposure	N/A	Delivers tightly contoured beams synchronized precisely to tumor motion resulting in minimal healthy tissue exposure
Stereotactic Frames	Immobilization devices used. Low dose per fraction reduces need for accuracy	Required in most Intracranial & Extracranial cases	Requires invasive frames in all cases	No frame required

* RJ Maciunas, RL Galloway Jr, JW Latimer. The application accuracy of stereotactic frames. *Neurosurgery* 35(4): 682–695, Oct 1994