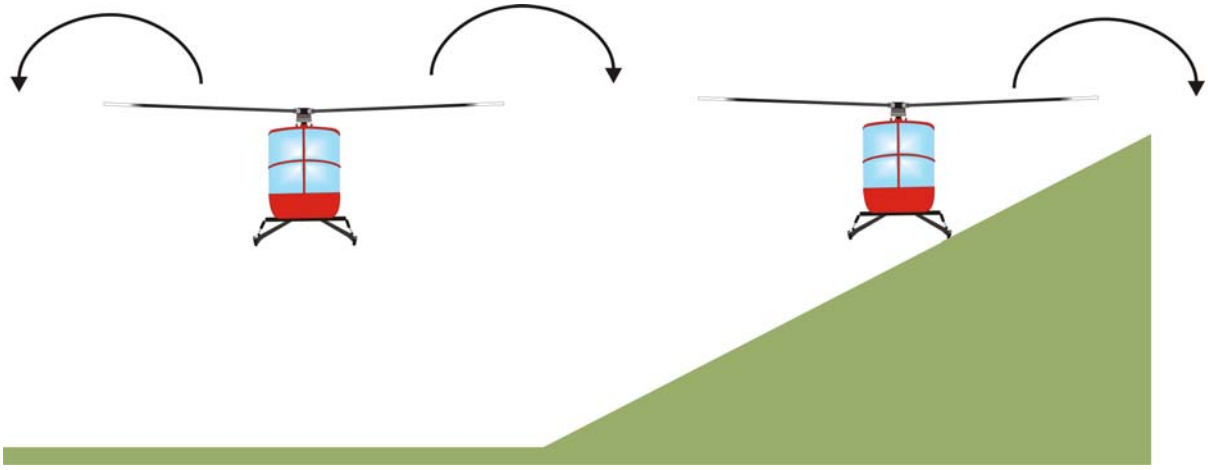
DANGEROUS HELICOPTER PRINCIPLES OF FLIGHT

DYNAMIC ROLL OVER

When a helicopter is lifting off the ground (or a surface) or is hovering with one skid or wheel on the ground, the helicopter may begin a rolling motion, which under certain circumstances cannot be controlled. This is known as Dynamic Roll-over. The rollover can occur in either direction.

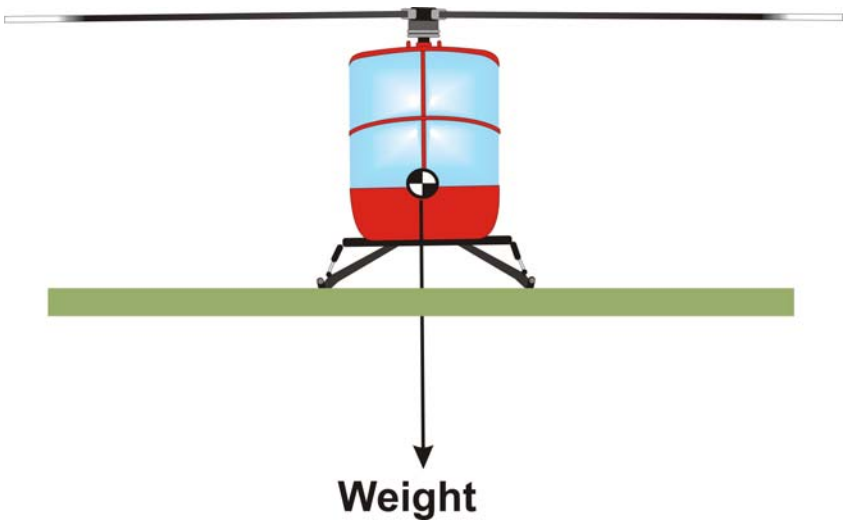


In general dynamic roll-over occurs when the pilot is too harsh and quick on the controls, not noticing that one skid is either stuck on the ground or the pilot has over controlled and caused the helicopter to commences a roll about the skid.

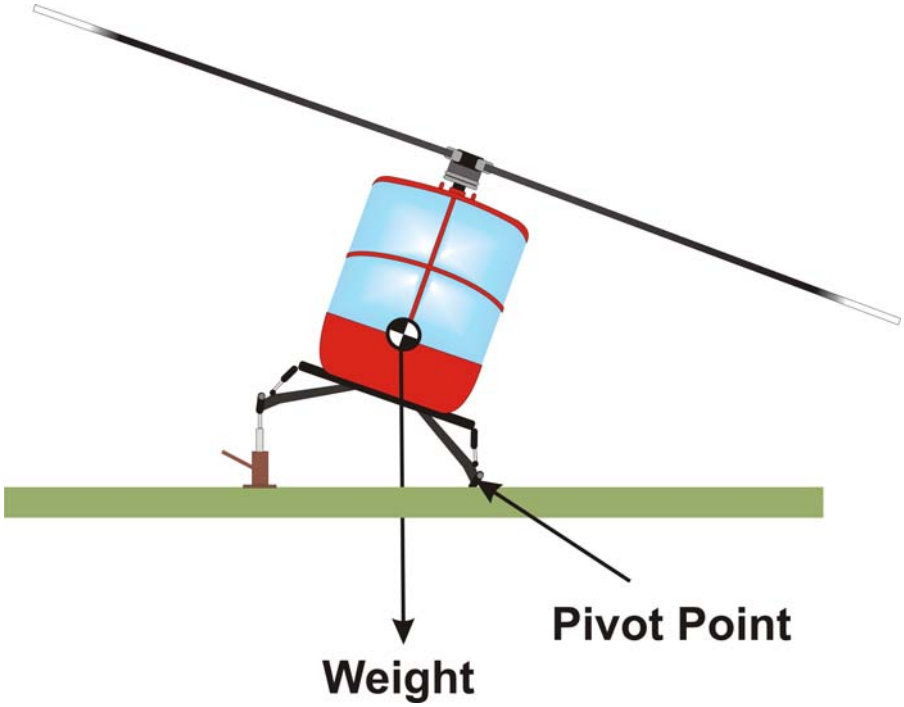
To understand dynamic rollover it helps to have an understanding of static rollover.

Static rollover

Consider a helicopter on the ground with the blades not turning and therefore no rotor thrust is being produced anywhere. For all intents and purposes then the helicopter is a lump of metal, plastic and fibreglass with the weight of all its parts bearing down towards the centre of the earth about its centre of gravity.



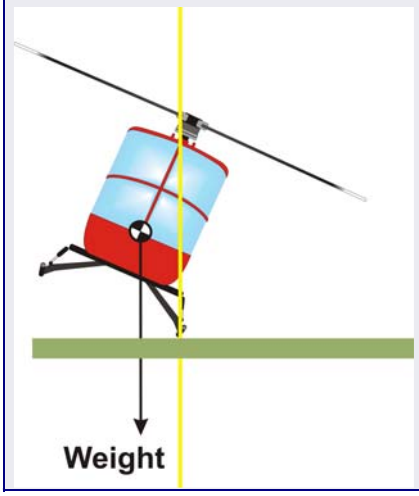
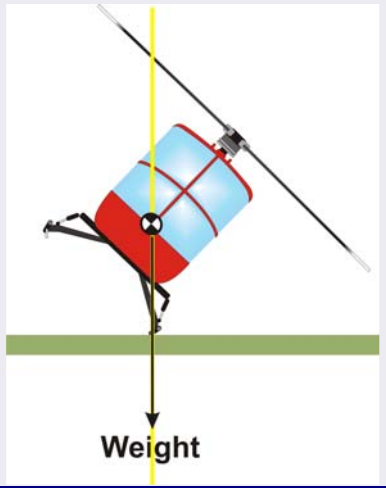
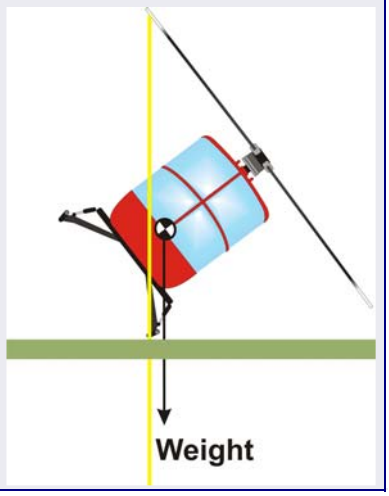
If we were to come along with a bottle jack (the type used to jack up a car when you have a flat tyre) and place it under the skid, you could lift the helicopter up off the ground. One skid would raise, the other would act as a pivot point about which the helicopter would be rotating.



The interesting thing here is, the helicopter will not roll over onto its side until the centre of gravity of the helicopter passes a line running vertically upwards from the pivot point.

At any time prior to reaching that point the jack could be removed and weight would cause the helicopter to settle back onto its skids.

Once the centre of gravity of the helicopter has reached the vertical line it would be balancing on the one skid. Once the centre of gravity goes slightly over the vertical line the helicopter will roll onto its side.

Weight pulls heli to ground	Balance Point	Weight pulls heli over
		

In an R22 the helicopter can reach a critical angle of 42° before it reaches the point where it will roll over. What has been described is static rollover where the helicopter is not under power.

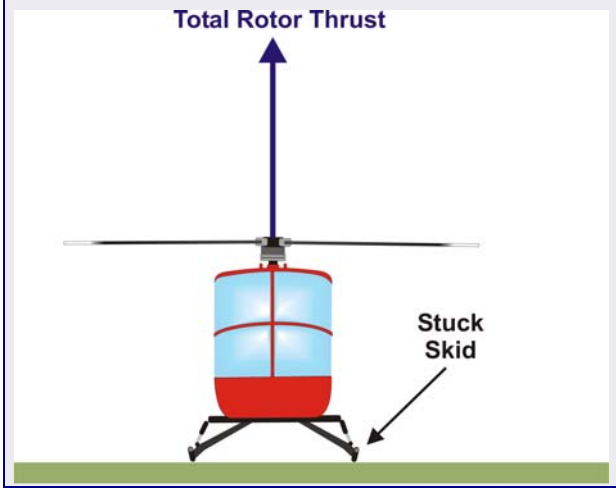
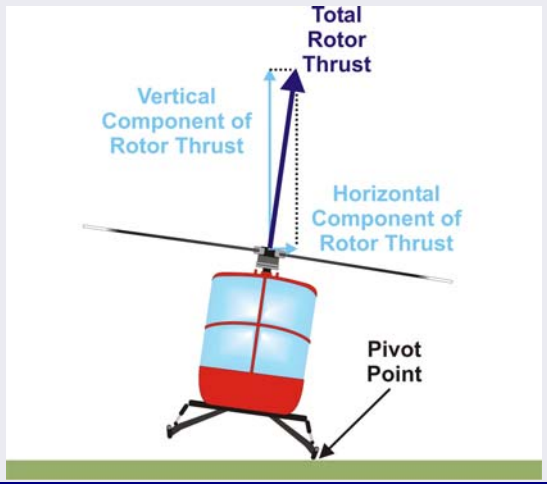
Why then can a helicopter experience dynamic rollover where the critical angle may be as low as 3° before control is lost and the helicopter rolls over onto its side.

Dynamic rollover

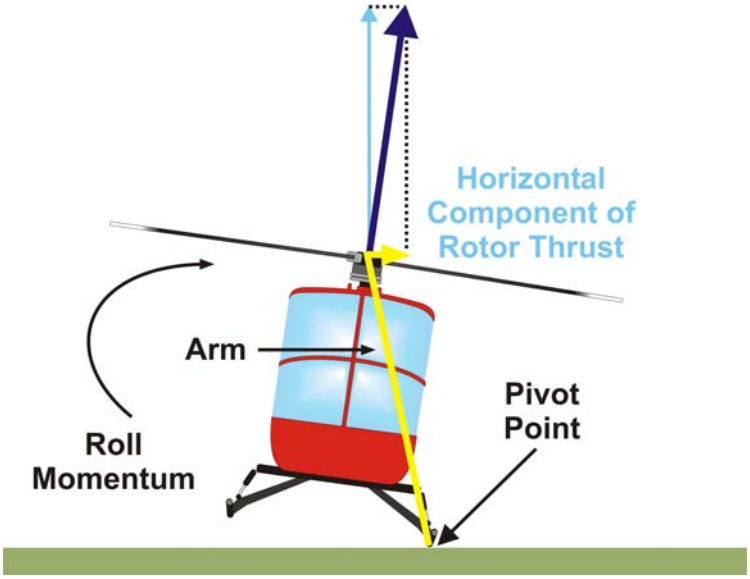
Consider a helicopter lifting off the ground and one skid becomes stuck.

The pilot continues to increase rotor thrust by raising the collective and the helicopter tries to lift off but now commences a roll towards the stuck skid. (the pivot point)

Assuming the pilot does not move the cyclic the rotor disc will now be tilted slightly towards the stuck skid. This will give a horizontal component of rotor thrust. This horizontal component acts from the rotor head along the length of the arm to the pivot point. You have effectively created a moment or a lever that is also trying to roll the helicopter over.

Increasing Rotor Thrust	Roll Begins
	

The helicopter as it starts to roll experiences an increase in momentum and will want to continue to roll unless another force is applied to stop it.



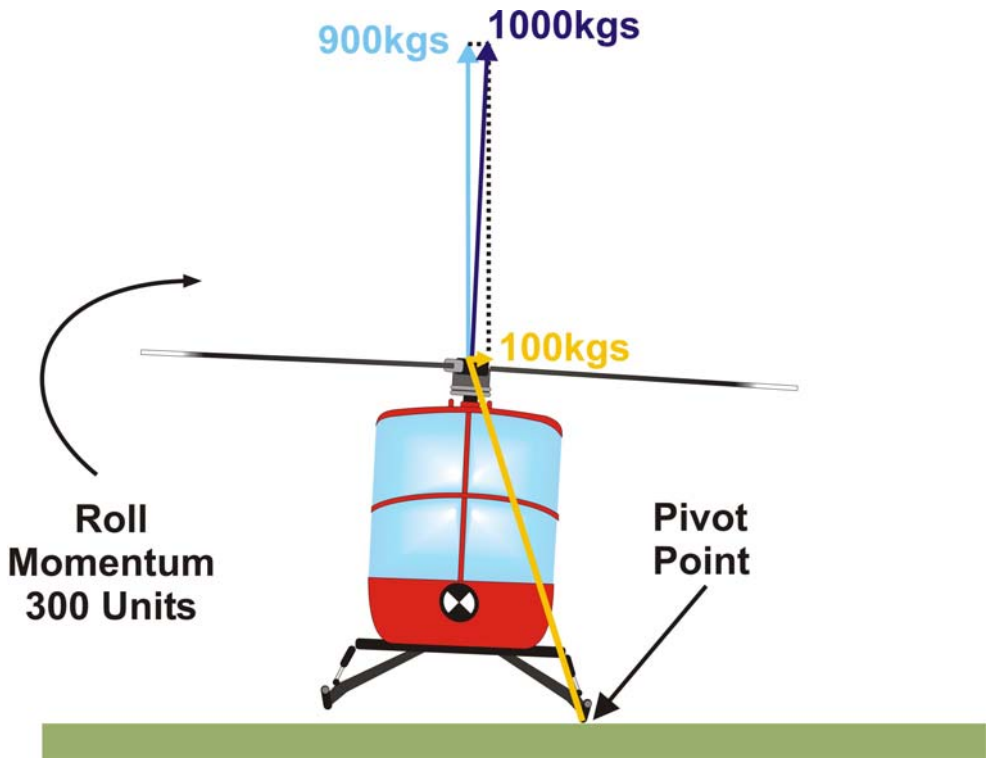
In normal free flight (both skids off the ground) the pilot is able to use the cyclic to counter any roll. Use of the cyclic produces a couple between the horizontal component of rotor thrust and the centre of gravity of the helicopter. The cyclic is only able to handle a certain amount of roll rate. If you exceed the designer's limit to the roll rate then opposite cyclic will have no effect. Now I do not know the particular numbers for each helicopter but lets assume for our hypothetical helicopter the cyclic is designed to handle no more than a roll rate of 10° per second or 10000 units of roll momentum which ever comes first.

Lets go back to our helicopter that is just starting to experience a roll and put some numbers into a calculation.

Lets assume the helicopter weights 1000kgs all up weight. That the distance from the pivot point (skid) to the rotor head is 3 meters and that the design limitation of the cyclic is 10° of roll per second, which may equate to 10000 units of, roll momentum.

As we are lifting off the rotor thrust would be increasing to be equivalent to almost 1000kgs of thrust (wouldn't get off the ground otherwise)

The helicopter would look like the following



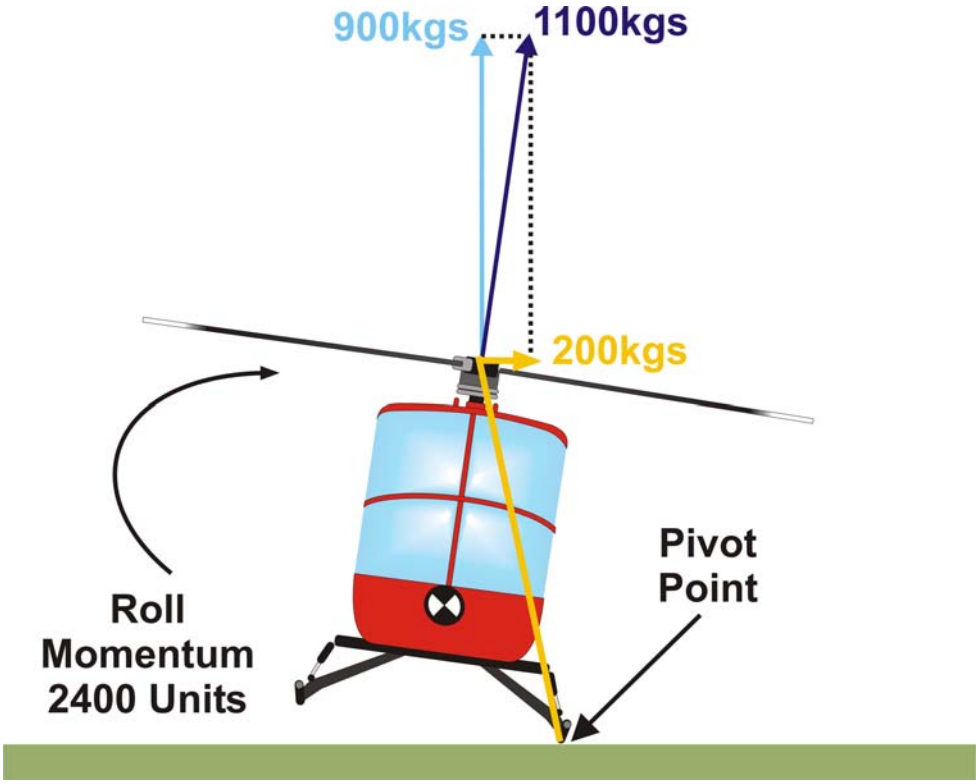
Mathematically it could be described as follows

Horizontal component of rotor thrust x the arm to the pivot point x the roll rate squared = units of roll momentum being experienced by the helicopter

Therefore

100kgs x 3m x $1°^2$ of roll per second = 300 units of roll momentum (less then 10,000 units)

At this point the roll is quite controllable with cyclic and the pilot is not in any danger. Lets say he ignores the early warning signs and continues to pull the collective without arresting the roll. The helicopter now rolls over further, its rate of roll increases and everything starts to happen very quickly.

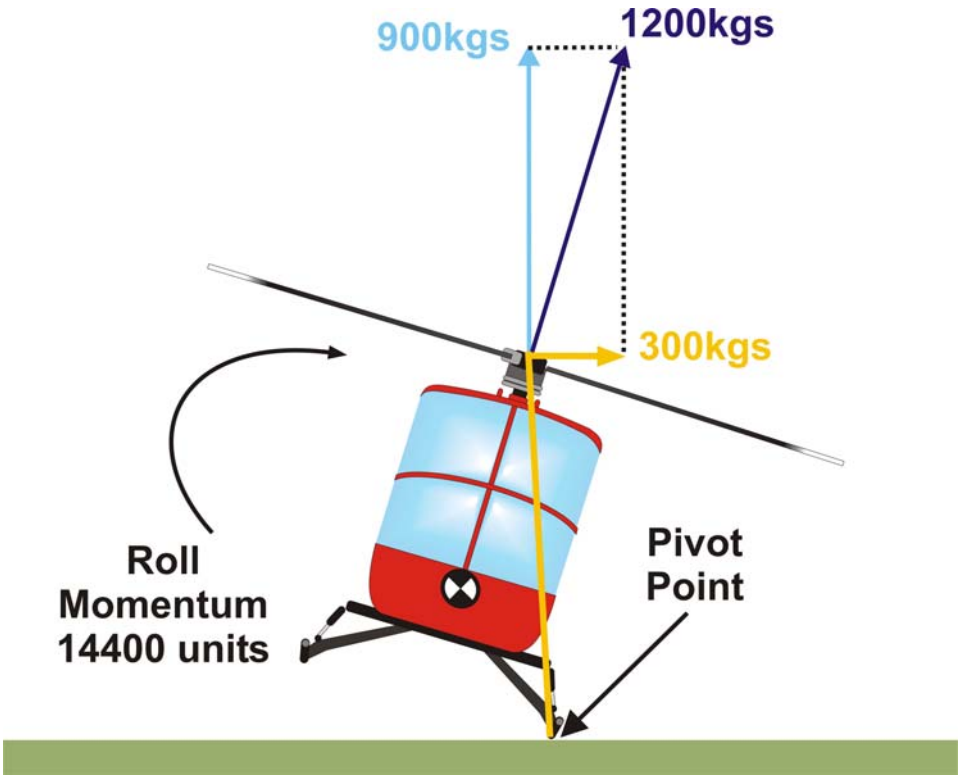


Mathematically it may look something like

200kgs x 3m x $2°^2$ of roll per second = 2400 units of roll momentum.

Notice that the roll momentum has not just doubled it has increased by a factor of 8.

At this point the helicopter is well on its way, it may still be controllable if the helicopters weight is sufficient to overcome the roll momentum, but it is definitely getting scary. The pilot needs to lower the collective and use some opposite cyclic and hope that the reorientation and eradication of some rotor thrust and the weight of the helicopter will allow the helicopter to fall back level to the ground. In most cases though the pilot starts to panic a little here and pulls the collective up more hoping to reef the helicopter off the ground and free the stuck skid.



Mathematically it may progress to something like

300kgs x 3m x $4°^2$ of roll per second = 14400 units of roll momentum.

The helicopter is definitely a goner now and there is no recovery. The helicopter is rolling over due to the excessive roll momentum even though it has only rolled a total say 7° from level.

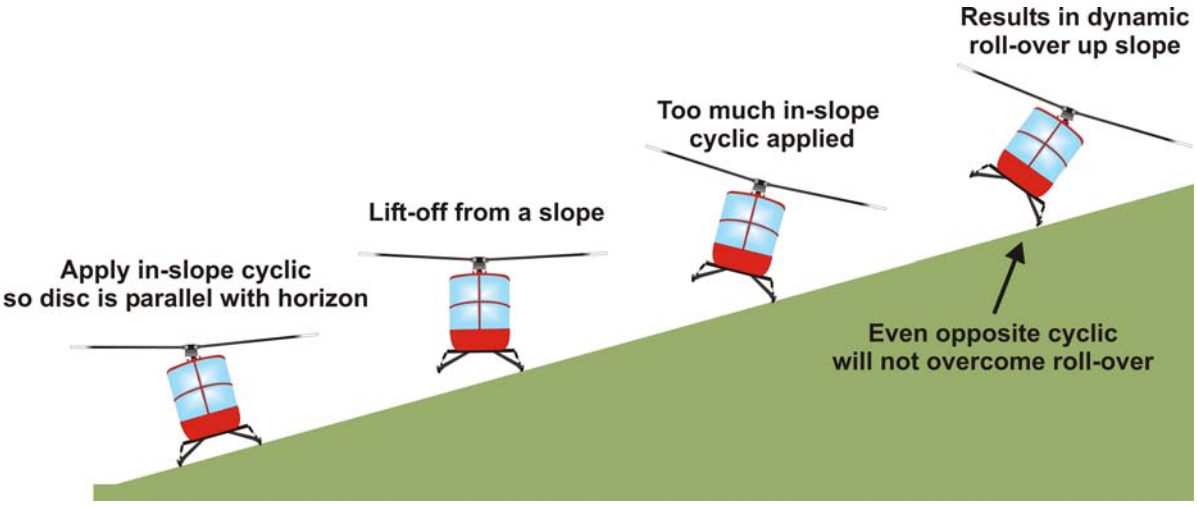
The pilot has experienced Dynamic rollover if the units of roll momentum looked like they were increasing at a very quick exponential rate just wait till you experience it.

Summary

Dynamic rollover may occur at any time a part of the helicopter comes in contact with a solid object. It is particularly relevant when lifting off and landing or at a hover. Experiencing dynamic rollover is really more of a problem with the pilot not recognising the early symptoms and being inattentive. The possibility will always exist and the potential for disaster is only seconds away.

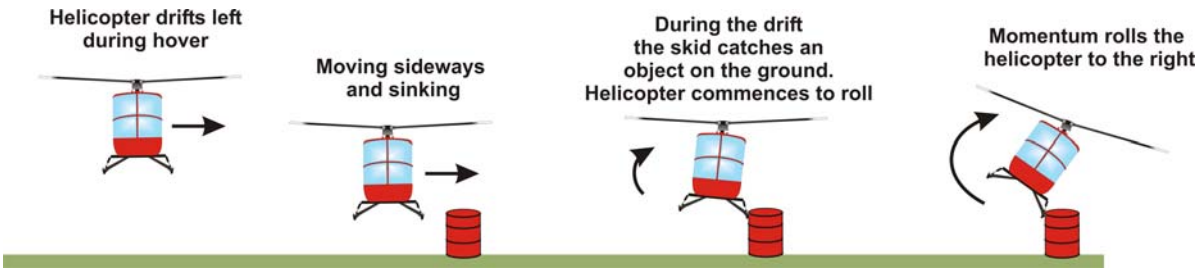
Several common scenarios that may induce dynamic rollover include

Over use of the cyclic when lifting off or landing on sloping ground. The roll can be amplified either way depending on the pilot's use of cyclic.



Experiencing tail rotor drift or roll and not compensating

Lifting off close to a refuelling drum and not correcting for any sideways drift



Watch the video Sloping and uneven landings by Becker Helicopters