

# *therascreen*<sup>®</sup> KRAS RGQ PCR Kit

## Instructions for Use (Handbook)



24

Version 1

**IVD**

For In Vitro Diagnostic Use

**Rx ONLY**

For prescription use only

For use with Rotor-Gene<sup>®</sup> Q MDx (US) instrument

For use with QIAamp<sup>®</sup> DSP DNA FFPE Tissue Kit

**REF**

870021



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R16

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# Intended Use

The *therascreen*<sup>®</sup> KRAS RGQ PCR Kit is a real-time qualitative PCR assay used on the Rotor-Gene Q MDx (US) instrument for the detection of seven somatic mutations in the human *KRAS* oncogene, using DNA extracted from formalin-fixed, paraffin-embedded (FFPE), colorectal cancer (CRC) tissue and non-small cell lung cancer (NSCLC) tissue. The test is intended as a companion diagnostic to identify patients who may benefit from treatment with the targeted therapies listed in Table 1 in accordance with the approved therapeutic product labeling.

**Table 1. Companion diagnostic indications**

Indication	Biomarker	Therapy
Colorectal cancer (CRC)	<i>KRAS</i> wild-type (absence of mutations in codons 12 and 13)	Erbix <sup>®</sup> (cetuximab)  Vectibix <sup>®</sup> (panitumumab)
Colorectal cancer (CRC)	<i>KRAS</i> G12C	Krazati <sup>®</sup> (adagrasib) in combination with Erbix <sup>®</sup> (cetuximab)
Colorectal cancer (CRC)	<i>KRAS</i> G12C	LUMAKRAS <sup>™</sup> (sotorasib) in combination with Vectibix <sup>®</sup> (panitumumab)
Non-small cell lung cancer (NSCLC)	<i>KRAS</i> G12C	LUMAKRAS (sotorasib)  Krazati (adagrasib)

# Summary and Explanation

Mutations in the *KRAS* oncogene are frequently found in human cancers (1–3). The presence of these mutations correlates with a lack of response to certain EGFR inhibitor cancer therapies in patients with metastatic colorectal cancer (mCRC) (4, 5–13). Such mutations in the *KRAS* oncogene are present in around 40% of mCRC cases (14).

The *KRAS* G12C mutation specifically results in the expression of a form of the *KRAS* protein in which the Glycine residue at amino acid position 12 is replaced by a Cysteine residue.

- In NSCLC patients, this indicates potential eligibility for treatment with the targeted *KRAS* inhibitor LUMAKRAS™ (sotorasib) or Krazati® (adagrasib). This mutation is estimated to be present in around 13% of NSCLC cases (15).
- In CRC patients, this indicates potential eligibility for treatment with the targeted *KRAS* inhibitor LUMAKRAS (sotorasib) in combination with Vectibix (panitumumab) or Krazati (adagrasib) in combination with Erbitux (cetuximab). This mutation is estimated to be present in around 3% of CRC cases (16).

Using Scorpions® (17) and ARMS (Allele Refractory Mutation System) technologies (18, 19), the *therascreen* *KRAS* RGQ PCR Kit enables the detection of seven mutations in codons 12 and 13 of the *KRAS* oncogene against a background of wild-type genomic DNA (Table 2). Based on data in the COSMIC database (2012 v59), the seven mutations detected by the *therascreen* *KRAS* RGQ PCR Kit account for >97% of all reported *KRAS* mutations in CRC patients (20).

**Table 2. List of mutations and COSMIC identities**

Mutation	Base change	COSMIC ID*
GLY12ALA (G12A)	GGT>GCT	522
GLY12ASP (G12D)	GGT>GAT	521
GLY12ARG (G12R)	GGT>CGT	518
GLY12CYS (G12C)	GGT>TGT	516
GLY12SER (G12S)	GGT>AGT	517
GLY12VAL (G12V)	GGT>GTT	520
GLY13ASP (G13D)	GGC>GAC	532

\* COSMIC IDs are taken from the Catalog of Somatic Mutations in Cancer  
([www.sanger.ac.uk/genetics/CGP/cosmic](http://www.sanger.ac.uk/genetics/CGP/cosmic))

## Principle of the Procedure

The *therascreen* KRAS RGQ PCR Kit provides eight separate PCR amplification reactions: seven mutation specific reactions in codons 12 and 13 of exon 2 of the *KRAS* oncogene and a wild type control in exon 4. The principal components of the kit are explained below.

### Mutation reaction mixes

Each reaction mix uses a mutation-specific Amplification Refractory Mutation System (ARMS) primer to selectively amplify the mutated DNA and then a Scorpions primer to detect the amplification product.

### ARMS

Allele-specific amplification is achieved by ARMS which exploits the ability of *Taq* DNA polymerase to distinguish between a matched and a mismatched base at the 3' end of a PCR primer. When the primer is fully matched, the amplification proceeds with full efficiency. When the 3' base is mismatched, only low-level background amplification may occur. Therefore, a mutated sequence is selectively amplified even in samples where the majority of the DNA does not carry the mutation.

### Scorpions

Detection of amplification is performed using Scorpions. Scorpions are bi-functional molecules containing a PCR primer covalently linked to a probe. The probe incorporates the fluorophore carboxyfluorescein (FAM™) and a quencher. The latter quenches the fluorescence of the fluorophore. When the probe binds to the the ARMS amplicon during PCR, the fluorophore and quencher become separated, leading to a detectable increase in fluorescence.

## Control reaction

The Control Reaction Mix (tube CTRL) uses a Scorpions primer and an unlabeled primer to amplify a short sequence of exon 4 of the *KRAS* gene. The control reaction is used to determine if an appropriate level of amplifiable DNA is present in the sample and is a factor used in the analytical calculations that are used to determine mutation status.

## Internal control

Each of the 8 reaction mixes contains an internal control designed to detect failure of the reaction (e.g., due to the presence of inhibitors). The internal control employs a non-*KRAS* related oligonucleotide target sequence, an unlabeled primer, and a Scorpions primer labeled with hexachlorofluorescein (HEX™) in order to distinguish it from the FAM-labeled Scorpions in the control and mutation reactions.

## Positive control

The *therascreen* KRAS RGQ PCR Kit also contains the KRAS Positive Control (tube PC). The positive control is a mixture of synthetic oligonucleotides representing each of the mutations detected by the kit. Detection of the positive control confirms the proper functioning of each of the reaction mixes in the kit.

## Negative control

The *therascreen* KRAS RGQ PCR Kit contains nuclease-free water for no template control (tube NTC) to be used for the “no template control” reaction. The no template control serves as a negative control and assesses potential contamination during assay setup.

## Taq DNA polymerase

Taq DNA polymerase is the enzyme for the polymerase chain reaction used by the *therascreen* KRAS RGQ PCR Kit.

## Platform and software

The *therascreen* KRAS RGQ PCR Kit is specifically designed for use with the Rotor-Gene Q MDx (US) instrument installed with the *therascreen* KRAS Assay Package, available for download at [www.qiagen.com](http://www.qiagen.com).

- Refer to "Materials Required but not Provided" on page 15, for compatible RGQ software and *therascreen* KRAS Assay Package versions.
- Refer to the instrument user manual for information concerning the instrument.
- To minimize flags for the controls and samples, strict compliance to the *therascreen* KRAS RGQ PCR Kit Instructions for Use guidance should be followed with respect to placement of the Rotor-Gene Q MDx (US) instrument according to Installation Procedures and site requirements.
- Refer to "Appendix: Installation of the Rotor-Gene Q *therascreen* KRAS Assay Package" on page 141, for instructions on installing the Rotor-Gene Q *therascreen* KRAS Assay Package.

The Rotor-Gene Q MDx (US) instrument must be maintained according to the requirements in the instrument user manual.

## Run parameters

The Rotor-Gene Q MDx (US) instrument is programmed for different cycle parameters, or "runs," by the *therascreen* KRAS Assay Package. The *therascreen* KRAS Assay Package consists of two templates:

- The *therascreen* KRAS QC Locked Template (for DNA sample assessment)
- The *therascreen* KRAS Locked Template (for detection of KRAS mutations)

These assay templates contain the PCR run parameters and calculate the results. The same run parameters are used for both the DNA sample assessment with the Control Reaction Mix and for detection of KRAS mutations using the mutation reaction mixes.

1. Hold at 95°C for 15 minutes to activate the *Taq* DNA polymerase.
2. PCR for 40 cycles of 95°C for 30 seconds to denature, and 60°C for 1 minute to anneal and extend.

The PCR cycle at which the fluorescence from a particular reaction crosses the predefined threshold value given by *therascreen* KRAS Assay Package is defined as the  $C_T$  value.

By using the control reaction to assess the DNA sample, it is possible based on the  $C_T$  values obtained to determine if the samples contain DNA levels that are suitable for analysis, and which samples require dilution prior to analysis.

Assessing the sample using the different mutation reaction mixes to determine their respective  $C_T$  values allows the *therascreen* KRAS Assay Package software to perform a calculation to determine the  $\Delta C_T$  value of the sample using the equation:

$$\Delta C_T = [\text{mutation assay } C_T \text{ value}] - [\text{control assay } C_T \text{ value}]$$

Based on predetermined analytical  $C_T$  and  $\Delta C_T$  values, the Rotor-Gene Q software qualitatively determines the mutation status of the DNA samples and reports which samples contain which mutation.\*

\*Rarely, a tumor may contain more than one mutation. In such instances, the mutation yielding the lowest  $\Delta C_T$  value will be identified.

## Reagents

Reaction mixes are duplex, containing FAM-labeled reagents to detect targets and HEX-labeled reagents to detect internal controls. The reaction mixes and positive control reagents contain Tris EDTA (ethylenediaminetetraacetic acid) buffer, and the positive control contains the carrier nucleic acid Poly A RNA.

**Table 3. Reagents supplied in the *therascreen* KRAS RGQ PCR Kit**

Reagent	Ingredients	Quantity
Control Reaction Mix	Control Unlabeled Primer, Control Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	2 tubes x 600 µL
12ALA Reaction Mix	12ALA ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL
12ASP Reaction Mix	12ASP ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL
12ARG Reaction Mix	12ARG ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL
12CYS Reaction Mix	12CYS ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL
12SER Reaction Mix	12SER ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL

**Table 3. Reagents supplied in the thescreen KRAS RGQ PCR Kit (continued)**

Reagent	Ingredients	Quantity
12VAL Reaction Mix	12VAL ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL
13ASP Reaction Mix	13ASP ARMS Primer, Scorpions Primer, Internal Control Unlabeled Primer, Internal Control Scorpion Primer, Internal Control Template, Deoxynucleotide Triphosphates, Magnesium Chloride, Tris EDTA Buffer, PCR Buffer	1 tube x 600 µL
KRAS Positive Control	Control Template, 12ALA Template, 12ASP Template, 12ARG Template, 12CYS Template, 12SER Template, 12VAL Template, 13ASP Template, Poly A RNA, Tris EDTA Buffer	1 tube x 250 µL
Taq DNA Polymerase	Taq DNA Polymerase: 50% glycerol/water	1 tube x 80 µL
No template control	Nuclease-free water	1 tube x 1.9 mL
For template dilution	Nuclease-free water	1 tube x 1.9 mL

# Materials Provided

## Kit contents

<i>therascreen</i> KRAS RGQ PCR Kit				(24)
Catalog no.				870021
Number of preps				24
Color	Identity	Tube identification		Volume
Red	Control Reaction Mix	1	CTRL	2 x 600 µL
Purple	12ALA Reaction Mix	2	12ALA	600 µL
Orange	12ASP Reaction Mix	3	12ASP	600 µL
Pink	12ARG Reaction Mix	4	12ARG	600 µL
Green	12CYS Reaction Mix	5	12CYS	600 µL
Yellow	12SER Reaction Mix	6	12SER	600 µL
Gray	12VAL Reaction Mix	7	12VAL	600 µL
Blue	13ASP Reaction Mix	8	13ASP	600 µL
Beige	KRAS Positive Control	9	PC	250 µL
Mint	<i>Taq</i> DNA Polymerase		<i>Taq</i>	80 µL
White	Nuclease-free water for no template control		NTC	1.9 mL
White	Nuclease-free water for dilution		Dil.	1.9 mL

# Materials Required but not Provided

When working with chemicals, always wear a suitable lab coat, disposable gloves, and protective goggles. For more information, consult the appropriate safety data sheets (SDSs), available from the product supplier.

Make sure that instruments have been checked and calibrated according to the manufacturer's recommendations.

- Fresh scalpel, razor blade, or similar sharp bladed instrument
- 0.1 mL Strip Tubes and Caps, for use with 72-well rotor (QIAGEN, cat. no. 981103 or 981106)
- Nuclease-free microcentrifuge tubes for preparing master mixes
- Sterile pipette tips with aerosol barriers
- Permanent marker
- Rotor-Gene Q MDx (US) instrument with 72-well rotor (QIAGEN, cat. no. 9002035)
- Rotor-Gene Q Software version 2.3.1 or later with *therascreen* KRAS Assay Package CD version 3.1.1 (QIAGEN, cat. no. 9023818)

**Note:** The Rotor-Gene Q *therascreen* KRAS Assay Package software will only work with software version 2.3.1 or later.

**Note:** Previous versions of the assay package are not compatible with the new software version 2.3.1 or later.

- Loading Block 72 x 0.1 mL Tubes, aluminum block for manual reaction setup (QIAGEN, cat. no. 9018901)
- Dedicated pipettes (adjustable) for sample preparation

- Dedicated pipettes (adjustable) for PCR master mix preparation
- Dedicated pipettes (adjustable) for dispensing of template DNA
- Thermomixer, heated orbital incubator, heating block, or water bath capable of incubation at 56°C, 70°C, and 90°C
- Benchtop centrifuge with rotor for 1.5 mL tubes
- Benchtop vortexer
- QIAamp DSP DNA FFPE Tissue Kit (QIAGEN, cat. no. 60404; see "Protocol: DNA Extraction" on page 25)

# Warnings and Precautions

## Warnings

For in vitro diagnostic use

For prescription use only

For use with Rotor-Gene Q MDx (US) instrument

For use with QIAamp DSP DNA FFPE Tissue Kit

When working with chemicals, always wear a suitable lab coat, disposable gloves, and protective goggles. For more information, please consult the appropriate safety data sheets (SDSs). These are available online in convenient PDF at [www.qiagen.com/safety](http://www.qiagen.com/safety) where you can find, view, and print the SDS for each QIAGEN kit and kit component.

## Precautions

The user must always adhere to the following precautions when using the *therascreen* KRAS RGQ PCR Kit:

- The test is for use with formalin-fixed, paraffin-embedded tissue specimens.
- All chemicals and biological materials are potentially hazardous. Specimens and samples are potentially infectious and must be treated as biohazardous materials.
- Discard sample and assay waste according to your local safety procedures.
- Reagents for the *therascreen* KRAS RGQ PCR Kit are diluted optimally. Do not dilute reagents further as this may result in a loss of performance. Do not use reaction volumes

(reaction mix plus sample) of less than 25 µL.

- All reagents in the the *therascreen* KRAS RGQ PCR Kit are formulated specifically for use with the tests provided in the *therascreen* KRAS RGQ PCR Kit.
- All reagents supplied in the *therascreen* KRAS RGQ PCR Kit are intended to be used solely with the other reagents supplied in the same *therascreen* KRAS RGQ PCR Kit. Do not substitute the reagents in the *therascreen* KRAS RGQ PCR Kit or between *therascreen* KRAS RGQ PCR Kits, as this may affect performance.
- Only use the *Taq* DNA polymerase (tube *Taq*) that is provided in the *therascreen* KRAS RGQ PCR Kit. Do not substitute with *Taq* DNA polymerase from other kits of the same or any other type, or with *Taq* DNA polymerase from another supplier.
- Refer to the *Rotor-Gene Q MDx (US) User Manual* for additional warnings, precautions, and procedures.
- Do not use expired or incorrectly stored components.
- To minimize flags for the controls and samples, strict compliance to the *therascreen* KRAS RGQ PCR Kit *Instructions for Use* should be followed, including but not limited to:
  - Correct reagent mixing is required and must be ensured at each mixing step during the assay setup.
- Placement of the Rotor-Gene Q MDx (US) instrument according to the Installation Procedures and site requirements.

**Note:** Use extreme caution to prevent contamination of the control and reaction mix reagents with the synthetic materials that are contained in the positive control reagent.

**Note:** Use individual, dedicated pipets for setting up reaction mixes and adding positive control reagents.

**Note:** Perform preparation and dispensing of reaction mixes in an area separate from the one used for the addition of the positive control.

**Note:** Do not open the Rotor-Gene Q MDx (US) instrument until the run has finished.

**Note:** Do not open the Rotor-Gene Q tubes after the run has finished.

**Note:** Caution must be observed to ensure correct sample testing with emphasis to wrong sample entry, loading error, and pipetting error.

The following hazard and precautionary statements apply to components of the *therascreen* KRAS RGQ PCR Kit.

<i>Taq</i> DNA Polymerase	Contains: Ethoxylated nonylphenol. Harmful to aquatic life with long lasting effects. Avoid release to the environment. Wear protective gloves/ protective clothing/ eye protection/ face protection. Dispose of contents/ container to an approved waste disposal plant.
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# Reagent Storage and Handling

The *therascreen* KRAS RGQ PCR Kit is shipped on dry ice and must be frozen on arrival. If any component of the *therascreen* KRAS RGQ PCR Kit is not frozen on arrival, if the outer packaging has been opened during transit, or the shipment does not contain a packing note, Instructions for Use, or the reagents, please contact one of the QIAGEN Technical Service Departments or local distributors (visit [www.qiagen.com](http://www.qiagen.com)).

The *therascreen* KRAS RGQ PCR Kit should be stored immediately upon receipt at  $-30$  to  $-15^{\circ}\text{C}$  in a constant-temperature freezer and protected from light. When stored under the specified storage conditions, the *therascreen* KRAS RGQ PCR Kit is stable until the stated expiration date.

Once opened, reagents can be stored in their original packaging at  $-30$  to  $-15^{\circ}\text{C}$  for 12 months or until the stated expiration date shown on the packaging. Repeated thawing and freezing should be avoided. Do not exceed a maximum of 6 freeze-thaw cycles.

The reagents must be thawed at room temperature for a minimum of 1 hour and a maximum of 4.5 hours. Once the reagents are ready to use, the PCR reactions can be set up. The Rotor Gene Q tubes, containing the master mixes and the DNA sample, can be loaded onto the Rotor-Gene Q MDx (US) immediately. The total time prior to run once the PCR reactions are set up should not exceed:

- 7 hours if stored at room temperature

**Note:** This time includes both the PCR setup and storage.

- 18 hours if stored in the refrigerator ( $2$ – $8^{\circ}\text{C}$ )

**Note:** This time includes both the PCR setup and storage.

**Note:** Scorpions (as with all fluorescently labeled molecules) in the reaction mix reagents are light sensitive. Protect control and reaction mix reagents from light to avoid photo bleaching.

Reagents in the *therascreen* KRAS RGQ PCR Kit are diluted optimally and no further purification or treatment is required prior to their use in analysis as directed by the *therascreen* KRAS RGQ PCR Kit Instructions for Use (this document).

Attention should be paid to the expiration dates and storage conditions printed on the box and labels of all components. Do not use expired or incorrectly stored components.

# Specimen Handling and Storage

## Specimen handling

The *therascreen* KRAS RGQ PCR Kit is for use on DNA samples extracted from FFPE tumor tissue collected from CRC or NSCLC patients. Tumors are heterogeneous in terms of both genotype and phenotype. Mutation-positive tumors can contain wild-type DNA and similarly histology can show regions of non-tumor tissue. All tissue samples should be treated as potentially hazardous.

## Preparing tissue specimens for DNA extraction from CRC tissue

- Using standard materials and methods, fix the tissue specimen in 10% neutral buffered formalin (NBF), and embed the tissue specimen in paraffin. Using a microtome, cut 5  $\mu$ m serial sections from the paraffin block and mount them on glass slides.
- Use a trained individual (e.g., a pathologist) to assess a Hematoxylin & Eosin (H&E)-stained section for tumor content and area determination. Mark the stained slide to distinguish tumor from normal tissue. Use serial sections for DNA extraction.
- Use sections with >20% tumor content by area for processing without macrodissection (see below).
- For sections that are  $\leq$ 20% tumor content by area, macrodissect one or more sections. Discard the non-tumor tissue.
- For sections that are  $<4$  mm<sup>2</sup> in area, process two or more sections to increase the total tumor area to at least 4 mm<sup>2</sup> (applies to samples both with and without macrodissection). If macrodissection was performed, discard the non-tumor tissue.

- Scrape excess paraffin away from the tissue using a fresh scalpel, razor blade, or similar sharp bladed instrument.

**Note:** Use dry scalpels, razor blade, or similar sharp bladed instrument. Do not perform this step in a laminar flow or fume hood.

- Scrape the tumor tissue from the sections into labeled microcentrifuge tubes using a fresh scalpel, razor blade, or similar sharp bladed instrument for each sample.

## Preparing tissue specimens for DNA extraction from NSCLC tissue

- Using standard materials and methods, fix the tissue specimen in 10% NBF, and embed the tissue specimen in paraffin. Using a microtome, cut 5  $\mu$ m serial sections from the paraffin block and mount them on slides.
- A trained individual (e.g., a pathologist) must assess a H&E-stained section for tumor presence. Use serial sections for DNA extraction.
- Scrape excess paraffin away from the tissue using a fresh scalpel, razor blade, or similar sharp bladed instrument.
- Label, handle, and store tumor specimens, blocks, slides, samples, and microcentrifuge tubes ready for extraction in a controlled fashion according to local procedures.

## Specimen storage

Store CRC FFPE blocks and slides at room temperature. Slides may be stored in the dark at ambient temperature for up to 4 weeks prior to DNA extraction.

Store NSCLC FFPE blocks and slides in the dark at room temperature. NSCLC resection and core needle biopsy slides may be stored at ambient temperature for up to 70 weeks prior to DNA extraction. NSCLC fine needle aspirate slides may be stored at ambient temperature for up to 56 weeks prior to DNA extraction.

- Genomic DNA may be stored at 2–8°C for 1 week post extraction, then at –25 to –15°C up to 8 weeks before use.

# Protocol: DNA Extraction

## DNA extraction for CRC samples

Use the QIAamp DSP DNA FFPE Tissue Kit (QIAGEN, cat. no. 60404) with the modifications to the protocol described below for purifying genomic DNA from samples prepared from FFPE CRC specimens.

**Note:** The *therascreen* KRAS RGQ PCR Kit has been validated using DNA extracted using the QIAamp DSP DNA FFPE Tissue Kit. Do not use any other DNA extraction product.

Carry out the DNA extraction according to the instructions in the *QIAamp DSP DNA FFPE Tissue Kit Handbook* noting the following:

- See the *QIAamp DSP DNA FFPE Tissue Kit Handbook Instructions for Use* for preparation of specimens prior to DNA extraction.
- The QIAamp DSP DNA FFPE Tissue Kit must be used manually only. Do not use the automated protocol for the QIAcube® described in the *QIAamp DSP DNA FFPE Tissue Kit Handbook*.
- Use only the xylene/ethanol method for deparaffinization, as described in the *QIAamp DSP DNA FFPE Tissue Kit Instructions for Use*.
- Use molecular biology grade ethanol for all required steps.\*
- Use 1 x 5 µm section per extraction (unless the section has ≤20% tumor content or is <4 mm<sup>2</sup> in area; see "Preparing tissue specimens for DNA extraction from CRC tissue " on page 22 for more detail).

\*Do not use denatured alcohol, which contains other substances such as methanol or methyl ethyl ketone.

- Proteinase K digestion (as described in the *QIAamp DSP DNA FFPE Tissue Kit Instructions for Use*) must be performed for 1 hour.
- The samples must be eluted using 200 µL elution buffer (Buffer ATE) from the QIAamp DSP DNA FFPE Tissue Kit.

Store genomic DNA at 2–8°C for 1 week post-extraction, and then at –25 to –15°C for up to 8 weeks before use.

## DNA extraction for NSCLC samples

Use the QIAamp DSP DNA FFPE Tissue Kit (QIAGEN, cat. no. 60404) with the modifications to the protocol described below for purifying genomic DNA from samples prepared from FFPE NSCLC specimens.

**Note:** The *therascreen* KRAS RGQ PCR Kit has been validated using DNA extracted using the QIAamp DSP DNA FFPE Tissue Kit. Do not use any other DNA extraction product.

Carry out the DNA extraction according to instructions in the *QIAamp DSP DNA FFPE Tissue Kit Instructions for Use* noting the following:

- Use 2 x 5 µm sections per extraction.
- The QIAamp DSP DNA FFPE Tissue Kit must be used manually only. Do not use the automated protocol for the QIAcube described in the *QIAamp DNA FFPE Tissue Kit Handbook*.
- Use only the xylene/ethanol method for deparaffinization described in the *QIAamp DSP DNA FFPE Tissue Kit Instructions for Use*.
- Proteinase K digestion (as described in the *QIAamp DSP DNA FFPE Tissue Kit Instructions for Use*) must be performed for 1 hour.

- Add 60 µL elution buffer (ATE) from the QIAamp DSP DNA FFPE Tissue Kit and incubate for 2.5 minutes at room temperature.
- Centrifuge at full speed for 1 minute.
- Add a further 60 µL elution buffer (ATE) from the QIAamp DSP DNA FFPE Tissue Kit and incubate for 2.5 minutes at room temperature.
- Centrifuge at full speed for 1 minute.
- Store genomic DNA at 2–8°C for 1 week post-extraction, and then at –25 to –15°C for up to 8 weeks before use.

# Protocol: DNA Sample Assessment

This protocol is used to assess the total amplifiable DNA in samples.

## Important points before starting

**Note:** DNA sample assessment is not designed to detect the presence of PCR inhibitors as only the total amplifiable DNA in a sample is assessed using the control reaction.

**Note:** It is important to use the Control Reaction Mix as described below for this assessment and not spectrophotometry or other alternative methods. Heavily degraded DNA may not amplify even though the primers generate short DNA fragments.

- Up to 24 samples can be assessed using the Control Reaction Mix available.
- Use the Control Reaction Mix (tube CTRL) to assess the DNA prior to testing.
- For efficient use of the reagents in the *therascreen* KRAS RGQ PCR Kit, batch DNA samples as far as possible to create full runs. Testing samples individually or in smaller numbers uses up more reagents and reduces the overall number of samples that can be tested with a single *therascreen* KRAS RGQ PCR Kit.
- Do not vortex the *Taq* DNA polymerase (tube *Taq*) or any mix containing *Taq* DNA polymerase, as this may inactivate the enzyme.
- Pipet *Taq* DNA polymerase by carefully placing the pipet tip just under the liquid surface to avoid the tip being coated in excess enzyme.
- To minimize flags for the controls, strict compliance to the *therascreen* KRAS RGQ PCR Kit *Instructions for Use* is required with respect to correct reagent mixing and must be ensured at each mixing step during the assay setup.

Things to do before starting

- Make sure that the Rotor-Gene Q *therascreen* KRAS Assay Package is installed before first use of the Rotor-Gene Q MDx (US) instrument (see "Appendix: Installation of the Rotor-Gene Q *therascreen* KRAS Assay Package" on page 141).
- Before each use, all reagents need to be thawed completely for a minimum of 1 hour at room temperature (15–25°C), mixed by inverting 10 times , and centrifuged briefly to collect the contents at the bottom of the tube. Correct reagent mixing must be ensured during assay setup.
- Make sure that *Taq* DNA polymerase (tube *Taq*) is at room temperature (15–25°C) before each use. Centrifuge the tube briefly to collect the enzyme at the bottom of the tube.
- Make sure that all samples to be tested have been completely thawed, and then mixed by inverting 10 times and centrifuged briefly to collect the contents at the bottom of the tube.

Procedure

1. Completely thaw the control reaction mix (tube CTRL), nuclease-free water for No Template Control (NTC), and KRAS Positive Control (PC) at room temperature (15–25°C) for a minimum of 1 hour.

The times for thawing reagents, PCR setup, and storage before starting the run are indicated in Table 4.

Table 4. Thawing time, PCR setup times, and storage temperatures

Thaw time		Storage temperature after PCR setup	Maximum PCR setup and storage time
Minimum	Maximum		
1 hour	4.5 hours	Room temperature 15–25°C	7 hours
1 hour	4.5 hours	2–8°C	18 hours

**Note:** PCR setup is to be performed at room temperature. The term “storage” refers to the time between completion of PCR setup and start of the PCR run on the Rotor-Gene Q MDx (US) instrument.

**Note:** Bring *Taq* DNA polymerase (tube *Taq*) to room temperature (15–25°C) at the same time as the other reagents (see "Reagent Storage and Handling" on page 20). Centrifuge the tube briefly to collect the enzyme at the bottom of the tube.

2. When the reagents have thawed, mix them by inverting each tube 10 times to avoid localized concentrations of salts and then centrifuge briefly to collect the contents at the bottom of the tube.

**Note:** Samples should also be mixed by inverting them 10 times and then centrifuged briefly to collect the contents at the bottom of the sample tube.

**Note:** Correct reagent mixing must be ensured during the assay setup.

3. Prepare sufficient control assay master mixes (Control Reaction Mix [tube CTRL] plus *Taq* DNA polymerase [tube *Taq*]) for the DNA samples, one KRAS Positive Control (tube PC) reaction, and one nuclease-free water for no template control (tube NTC) reaction according to the volumes in Table 5.

Include reagents for 1 extra sample to allow sufficient overage for the PCR setup. The control assay master mix contains all of the components needed for the PCR, except the control or sample.

**Table 5. Preparation of Control assay master mix**

Component of control assay master mix	Volume required for master mix
Control Reaction Mix (tube CTRL)	19.76 µL x (n+1)*
Taq DNA polymerase (tube Taq)	0.24 µL x (n+1)*
<b>Total volume</b>	<b>20 µL/reaction</b>

\* n = Number of reactions (samples plus controls).

Prepare enough master mix for an extra sample (n+1) to allow for sufficient overage for the PCR setup. The value n should not exceed 24 (plus controls) as 24 is the maximum number of samples which can fit on a run.

**Note:** When preparing the control assay master mix, the required volume of the Control Reaction Mix is added to the relevant tube first and Taq DNA polymerase (Taq) is added last.

- Place the appropriate number of PCR 4-strip tubes (each strip has 4 tubes) in the loading block according to the layout in Table 6. Numbers denote positions in the loading block and indicate final rotor position. Do not cap the tubes.

**Note:** Leave the caps in the plastic container until required.

**Table 6. Run layout in the loading block for DNA sample assessment**

Assay									
Control	1 (PC)	9	17	25	–	–	–	–	–
Control	2 (NTC)	10	18	26	–	–	–	–	–
Control	3	11	19	–	–	–	–	–	–
Control	4	12	20	–	–	–	–	–	–
Control	5	13	21	–	–	–	–	–	–
Control	6	14	22	–	–	–	–	–	–

**Table 6. Run layout in the loading block for DNA sample assessment (continued)**

Assay									
Control	7	15	23	–	–	–	–	–	–
Control	8	16	24	–	–	–	–	–	–

- Set a pipet to a volume lower than the total reaction master mix volume and mix thoroughly by fully aspirating up and down 10 times.

**Note:** Correct reagent mixing must be ensured during assay setup.

- Immediately add 20 µL control assay master mix to each PCR strip tube. Refer to Table 6 for the tube layout.

**Note:** For DNA sample assessment, control assay master mix should be added to one PC tube, one NTC tube, and one tube for each DNA sample.

- Immediately add 5 µL of nuclease-free water for No Template Control (NTC) to the NTC tube (tube position 2) and cap the tube.
- Add 5 µL of each DNA sample to the sample tubes (tube positions 3–26) and cap the tubes.
- Add 5 µL of KRAS Positive Control (PC) to the PC tube (tube position 1) and cap the tube.

Each tube should contain a total reaction volume of 25 µL (20 µL of control assay master mix plus 5 µL of NTC/sample/PC).

- Using a permanent marker, mark the lids of the first tubes in the lowest numerical position in each PCR 4-strip tube (e.g., positions 1, 5, and 9, etc.) to show the orientation to load the tubes into the 72-well rotor of the Rotor-Gene Q MDx (US) instrument.

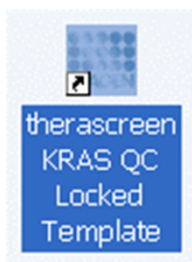
- Invert capped tubes 4 times to mix the sample and reaction mix.

**Note:** Correct reagent mixing must be ensured during assay setup.

12. Place all PCR 4 strip tubes into the appropriate positions of the 72-well rotor according to the run layout using the marks for orientation.

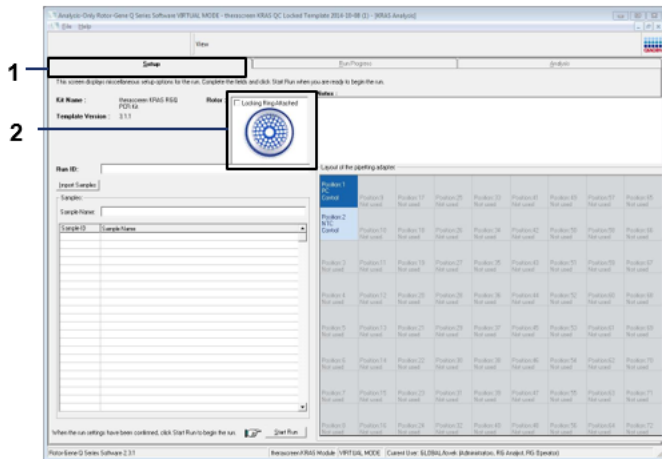
**Note:** If the rotor is not fully occupied, all unused positions on the rotor must be filled with a capped, empty tube. This ensures that the thermal efficiency of the Rotor Gene Q MDx (US) instrument is maintained.

13. Place the 72-well rotor into the Rotor-Gene Q MDx (US) instrument. Ensure that the locking ring (supplied with the Rotor-Gene Q MDx (US) instrument) is placed on top of the rotor to secure the tubes during the run.
14. To start the Rotor-Gene Q software and open the template at the same time, double-click the **therascreen KRAS QC Locked Template** icon on the desktop of the laptop connected to the Rotor-Gene Q MDx(US) instrument.



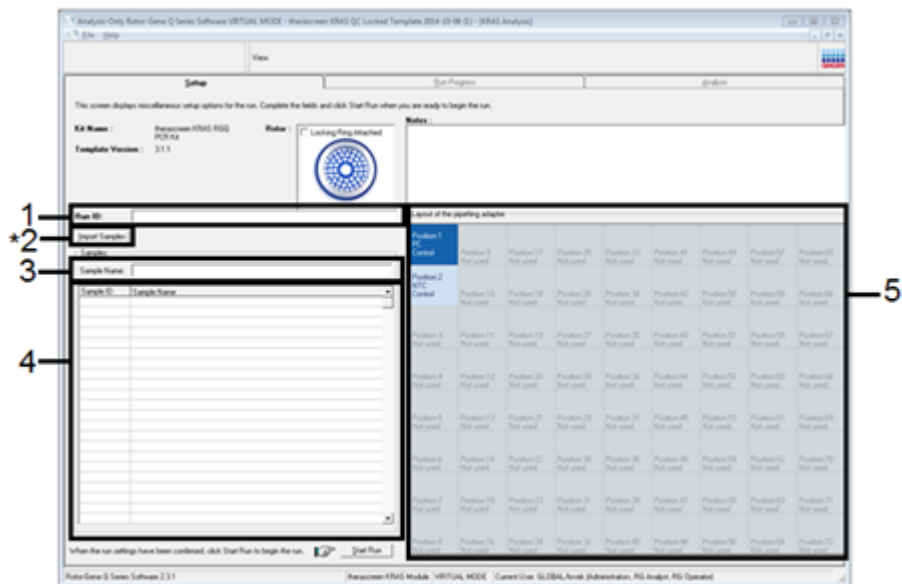
**Figure 1.** The *therascreen* KRAS QC Locked Template icon.

15. The Setup tab appears (1) as the default . Ensure that the locking ring is properly attached and check the **Locking Ring Attached** box (2). Close the lid of the Rotor-Gene Q MDx (US) instrument.



**Figure 2. The Setup tab and Locking Ring Attached box.** 1 = Setup tab, 2 = Locking Ring Attached box.

16. Enter the run ID in the **Run ID** field (1 in example below) according to your local naming convention.



17. Enter the sample name in the **Sample Name** field (3) according to your local naming convention and press the **Return** key.

This will add the sample name to the sample list below (4) and assign the sample a **Sample ID** (1, 2, 3, etc.). In addition, the **Layout of the pipetting adapter** (5) panel on the right side will update to include the sample name.

**Important:** Use caution when entering sample names to avoid mixing up the sample IDs. Alternatively, sample names stored in the \*.smp (Rotor-Gene Q sample file) or \*.csv (comma separated values) format can be imported using the **Import Samples** button (2). Sample names will be populated automatically using this method.

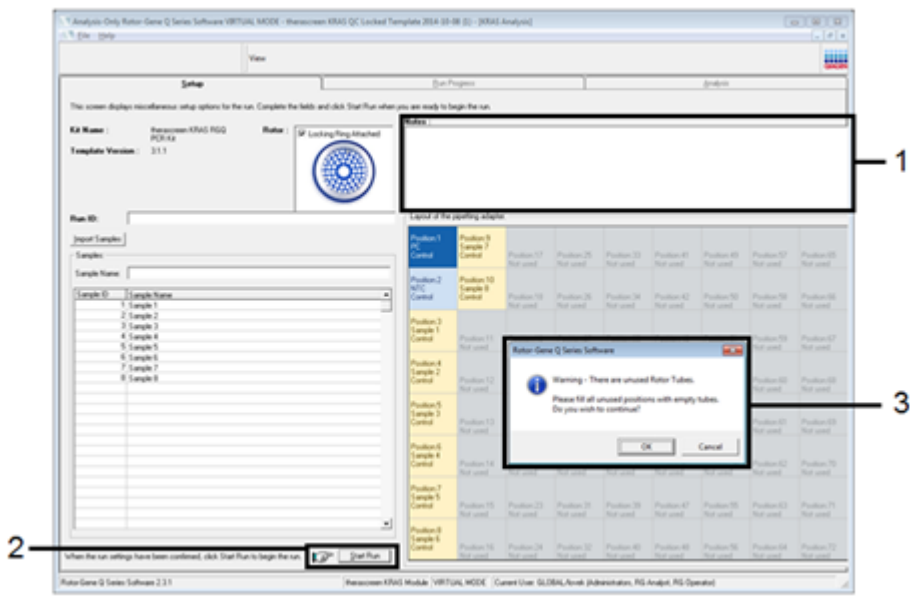
**Note:** In the **Layout of the pipetting adapter** panel, check that addition of the sample name has been highlighted by a change in color and that the sample name is in the sample position.

**Note:** Sample names with more than 8 characters may not completely display in the **Layout of the pipetting adapter** panel.

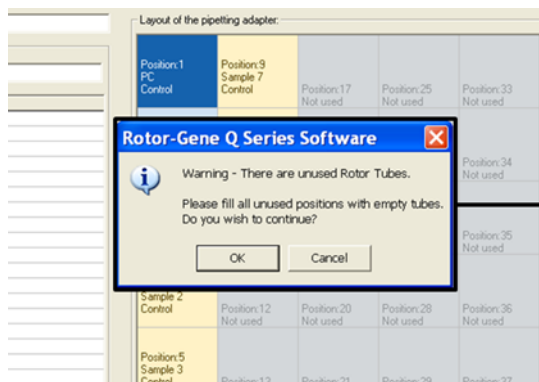
18. Repeat step 17 to enter the names of all additional samples.

**Note:** To edit a sample name, click **Sample Name** in the sample list (4) and the selected sample will appear in the **Sample Name** field (3) above. Edit the sample name according to your local naming convention and press the **Return** key to update the name. The additional sample names appear in the **Layout of the pipetting adapter** panel (5).

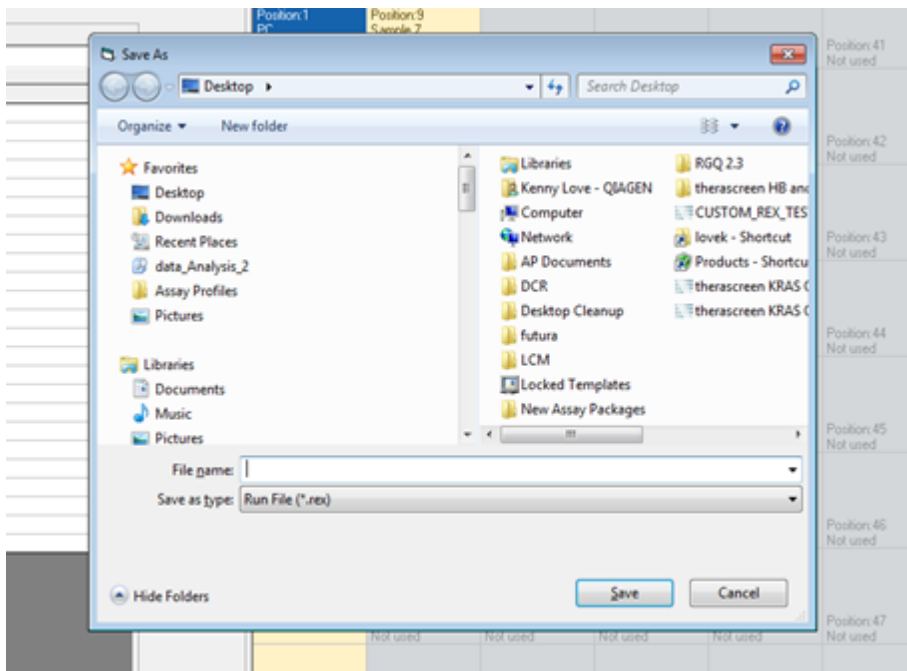
19. When all sample names have been entered, verify that they are correct. Add any additional information in the **Notes** field (1) if necessary, then click **Start Run** (2).



**Note:** If any rotor position is unused, a warning message will appear (3 and example below) to remind the user that all unused positions on the rotor must be filled with a capped, empty tube. Check that all unused rotor positions are filled with a capped, empty tube and click **OK** (1 in the example below) to proceed.

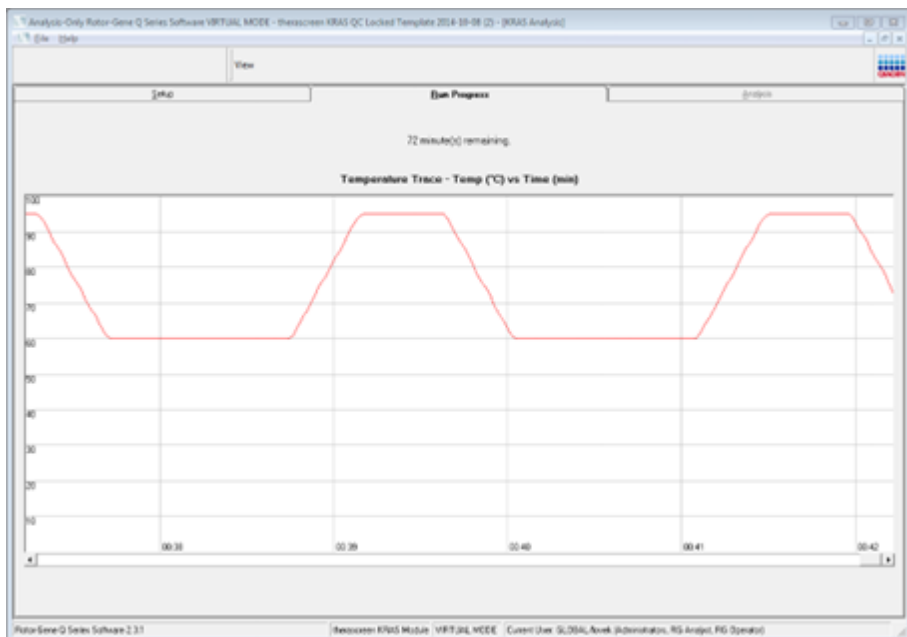


20. A Save As window appears. Select an appropriate file name and save the PCR run as a \*.rex run file to the selected location. Click **Save**.



21. The PCR run starts.

**Note:** When the run starts, the Run Progress tab will open automatically to show the temperature trace and remaining run time.



After the run is finished, the Analysis tab will open automatically. If the Analysis tab fails to open, click the **Analysis** tab.

The screenshot displays the 'Analysis' window of the Rotor-Gene Q Series Software. The 'QC Sample Result Table' is visible, showing results for 10 samples. The table has four columns: Tube ID, Sample Name, Control Accession, Flag/Percentage, and Status. Samples 1 and 2 are controls (PC Control and NTC Control), and samples 3 through 10 are various samples. All samples show a status of 'Valid'.

Tube ID	Sample Name	Control Accession	Flag/Percentage	Status
1	PC Control	27.48	-	Valid
2	NTC Control	-	-	Valid
3	Sample 1	27.48	-	Valid
4	Sample 2	27.63	-	Valid
5	Sample 3	28.36	-	Valid
6	Sample 4	28.36	-	Valid
7	Sample 5	28.36	-	Valid
8	Sample 6	28.16	-	Valid
9	Sample 7	27.63	-	Valid
10	Sample 8	28.36	-	Valid

## 22. Control results are reported in the QC Sample Result Table.

- Run controls (PC Control and NTC Control, tube positions 1 and 2 respectively):

If the results are within acceptable ranges, each will display a status of "Valid."

If the results are not within acceptable ranges, an "Invalid" result will appear.

- Sample Control reaction  $C_T$  is  $>32.00$ : an "Invalid" result will display.

Quantity of DNA is not sufficient for mutation analysis.

Retest the sample. If the quantity of DNA is still insufficient, extract more tumor tissue, if available (see "Rotor-Gene Q therascreen KRAS Assay Package flags" on page 59 and "Troubleshooting Guide" on page 66).

- Sample Control reaction  $C_T$  is  $<21.92$ : an “Invalid” result will display.

The DNA concentration is too high for mutation analysis.

Dilute with nuclease-free water for dilution (tube Dil.) and retest.

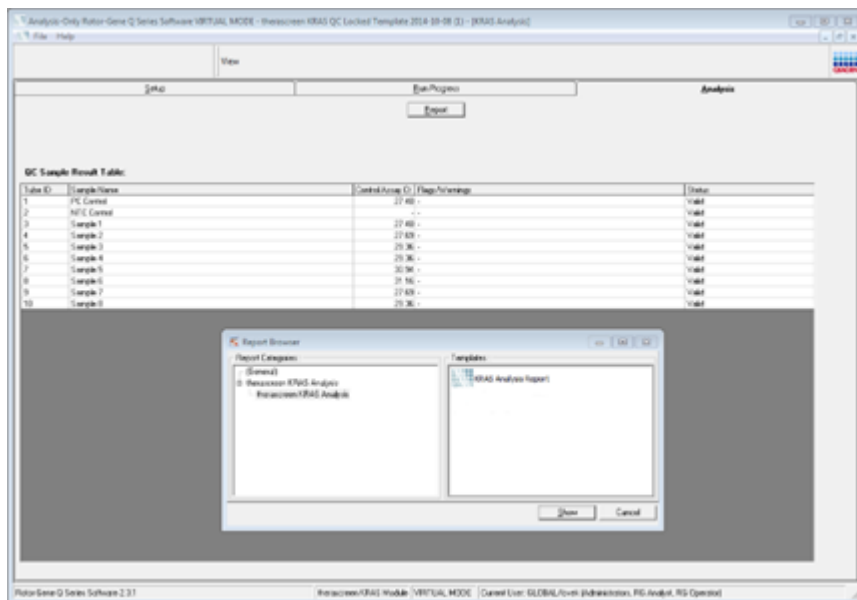
Dilute to a  $C_T$  of 21.92–32.00. A 1:1 dilution increases the  $C_T$  value by approximately 1.0.

- Sample Control reaction  $C_T$  is 21.92–32.00, (inclusive): a “Valid” result will display.

DNA concentration is suitable for mutation analysis.

**Note:** If re-extraction or dilution is required, repeat the control reaction to confirm that the DNA concentration is suitable for use.

23. Click **Report** to generate report files. The Report Browser window will appear. Select **KRAS Analysis Report** under Templates, then click **Show**.



**Note:** Reports can be saved to an alternative location in Web Archives format by clicking the **Save As** button on the top left corner of each report.

# Protocol: Detection of *KRAS* mutations

This protocol is for the detection of *KRAS* mutations.

## Important points before starting

- A sample can be tested using the *KRAS* mutation assays once it has passed the sample assessment.
- For efficient use of the *therascreen* *KRAS* RGQ PCR Kit, samples must be grouped into batches of 7 (to fill the 72-well rotor). Smaller batch sizes will mean that fewer samples can be tested with the *therascreen* *KRAS* RGQ PCR Kit.
- The sample must be tested using all reaction mixes provided in the *therascreen* *KRAS* RGQ PCR Kit.
- Do not vortex the *Taq* DNA polymerase (tube *Taq*) or any mix containing *Taq* DNA polymerase, as this may inactivate the enzyme.
- Pipet *Taq* DNA polymerase by carefully placing the pipet tip just under the liquid surface to avoid the tip being coated in excess enzyme.

**Note:** To minimize flags for the controls and samples, strict compliance to the *therascreen* *KRAS* RGQ PCR Kit Instructions for Use is required with respect to correct reagent mixing and must be ensured at each mixing step during the assay setup.

## Things to do before starting

- Before each use, all reagents need to be thawed completely for a minimum of 1 hour at room temperature (15–25°C), mixed by inverting 10 times, and centrifuged briefly to collect the contents at the bottom of the tube.

- Ensure that *Taq* DNA polymerase (tube *Taq*) is at room temperature (15–25°C) before each use. Centrifuge the tube briefly to collect the enzyme at the bottom of the tube.
- Ensure that all samples to be tested have been completely thawed, mixed by inverting 10 times, and centrifuged briefly to collect the contents at the bottom of the tube.

**Note:** Correct reagent mixing must be ensured during assay setup.

## Procedure

1. Completely thaw all reaction mix tubes, nuclease-free water for No Template Control (tube NTC), and KRAS Positive Control (tube PC) at room temperature (15–25°C) for a minimum of 1 hour.

The times for thawing reagents, PCR setup, and storage before starting the run are indicated in Table 7.

**Table 7. Thawing time, PCR setup times, and storage temperatures**

Thaw time			Maximum PCR setup and storage time
Minimum	Maximum	Storage* temperature after PCR setup	
1 hour	4.5 hours	Room temperature 15–25°C	7 hours
1 hour	4.5 hours	2–8°C	18 hours

**Note:** PCR setup is to be performed at room temperature. The term “storage” refers to the time between completion of PCR setup and start of the PCR run on the Rotor-Gene Q MDx (US) instrument.

**Note:** Bring *Taq* DNA polymerase (tube *Taq*) to room temperature (15–25°C) at the same time as the other reagents (see "Reagent Storage and Handling" on page 20). Centrifuge the tube briefly to collect the enzyme at the bottom of the tube.

2. When the reagents have thawed, mix them by inverting each tube 10 times to avoid localized concentrations of salts and then centrifuge briefly to collect the contents at the bottom of the tube. Samples should also be mixed by inverting them 10 times and then centrifuged briefly to collect the contents at the bottom of the sample tube.

**Note:** Correct reagent mixing must be ensured during assay setup.

3. Label 8 Nuclease-free microcentrifuge tubes (not provided) according to each corresponding reaction mix shown in the table below. Prepare sufficient master mixes (control or mutation reaction mix [tube CTRL, 12ALA, 12ASP, 12ARG, 12CYS, 12SER, 12VAL, or 13ASP] plus *Taq* DNA polymerase [*Taq*]) for the DNA samples, one KRAS Positive Control (tube PC) reaction, and one nuclease-free water for no template control (tube NTC) reaction according to the volumes in the table. Include reagents for 1 extra sample to allow sufficient overage for the PCR setup. The master mixes contain all of the components needed for PCR except the sample.

**Table 8. Master mix and corresponding volume\***

Assay and reaction mix tube	Volume of reaction mix	Volume of <i>Taq</i> DNA polymerase
Control (tube CTRL)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
12ALA (tube 12ALA)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
12ASP (tube 12ASP)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
12ARG (tube 12ARG)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
12CYS (tube 12CYS)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
12SER (tube 12SER)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
12VAL (tube 12VAL)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$
13ASP (tube 13ASP)	19.76 $\mu\text{L} \times (n + 1)$	0.24 $\mu\text{L} \times (n + 1)$

\*  $n$  = number of reactions (samples plus controls).

Prepare enough master mix for 1 extra sample ( $n + 1$ ) to allow for sufficient overage for the PCR setup. The value  $n$  should not exceed 7 (plus controls) as 7 is the maximum number of samples which can fit on a run.

**Note:** When preparing the assay master mixes, the required volume of the control or mutation reaction mix is added to the relevant tube first and the *Taq* DNA polymerase (tube *Taq*) is added last.

- Place the appropriate number of PCR 4-strip tubes (each strip has 4 tubes) in the loading block according to the layout in Table 9. Numbers denote positions in the loading block and indicate final rotor position. Do not cap the tubes.

**Note:** Leave the caps in the plastic container until required.

**Table 9. Run layout in the loading block for detection of *KRAS* mutations**

Assay	PC	NTC	1	2	3	4	5	6	7
CTRL	1 *	9	17	25	33	41	49	57	65

**Table 9. Run layout in the loading block for detection of KRAS mutations (continued)**

Assay	PC	NTC	1	2	3	4	5	6	7
12ALA	2	10	18	26	34	42	50	58	66
12ASP	3	11	19	27	35	43	51	59	67
12ARG	4	12	20	28	36	44	52	60	68
12CYS	5	13	21	29	37	45	53	61	69
12SER	6	14	22	30	38	46	54	62	70
12VAL	7	15	23	31	39	47	55	63	71
13ASP	8	16	24	32	40	48	56	64	72

- Set a pipet to a volume lower than the total reaction mix volume and thoroughly mix the assay master mixes by fully aspirating up and down 10 times.

**Note:** Correct reagent mixing must be ensured during assay setup.

For detection of *KRAS* mutations, 20 µL assay master mixes should be added to 8 PC tubes, 8 NTC tubes, and 8 tubes for each DNA sample.

- Immediately add 5 µL of nuclease-free water for No Template Control (NTC) to the NTC tubes (tube positions 9–16) and cap the tubes.
- Add 5 µL of each DNA sample to the sample tubes (tube positions 17–72) and cap the tubes.
- Add 5 µL of *KRAS* Positive Control (PC) to the PC tubes (tube positions 1–8) and cap the tubes.
- Using a permanent marker, mark the lids of the first tubes in the lowest numerical position in each PCR 4-strip tube (e.g. positions 1, 5, and 9 etc.) to show the orientation to load the tubes into the 72-well rotor of the Rotor-Gene Q MDx (US) instrument.
- Invert the capped tubes 4 times to mix the sample and reaction mix.

**Note:** Correct reagent mixing must be ensured during assay setup.

11. Place all PCR 4-strip tubes into the appropriate positions of the 72-well rotor according to the run layout using the marks for orientation.

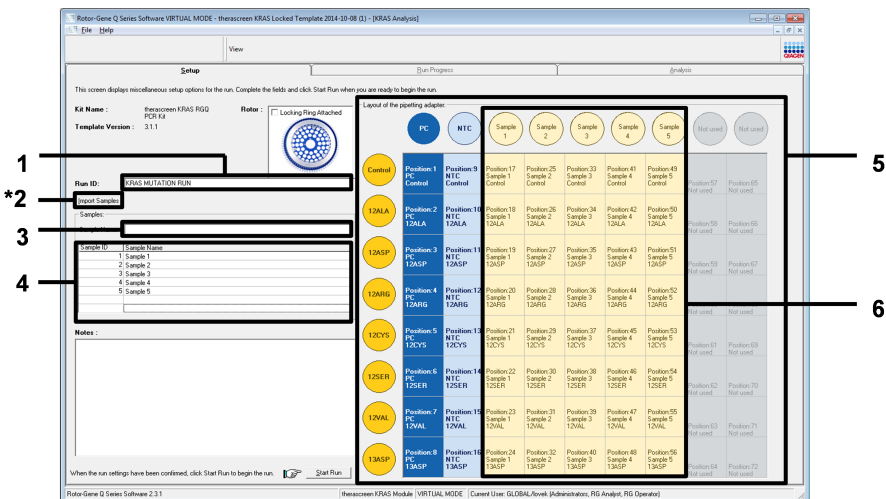
**Note:** A maximum of 7 samples can be included in each PCR run. If the rotor is not fully occupied, all unused positions on the rotor must be filled with a capped, empty tube. This ensures that the thermal efficiency of the Rotor-Gene Q MDx (US) instrument is maintained.

12. Place the 72-well rotor into the Rotor-Gene Q MDx (US) instrument. Ensure that the locking ring (supplied with the Rotor-Gene Q MDx (US) instrument) is placed on top of the rotor to secure the tubes during the run.
13. To start the Rotor-Gene Q software and open the template at the same time, double-click the **therascreen KRAS Locked Template** icon on the desktop of the laptop connected to the Rotor-Gene Q MDx (US) instrument.



14. The Setup tab appears (1) as the default. Ensure that the locking ring is properly attached and check the **Locking Ring Attached** box (2). Close the lid of the Rotor-Gene Q MDx (US) instrument.





16. Enter the sample name in the **Sample Name** field (3) according to your local naming convention and press the **Return** key.

**Important:** Use caution when entering sample names to avoid mixing up the sample IDs. This will add the sample name to the sample list below and assign the sample a **Sample ID** (1, 2, 3, etc.). In addition, the **Layout of the pipetting adapter** panel on the right side (5) will update to include the sample name.

Alternatively, sample names stored in the \*.smp (Rotor-Gene Q sample file) or \*.csv (comma separated values) format can be imported using the Import Samples button (2). Sample names will be populated automatically using this method.

**Note:** In the **Layout of the pipetting adapter** panel, check that addition of the sample name has been highlighted by a change in color and that all eight assays in the column under the sample circle are highlighted (6).

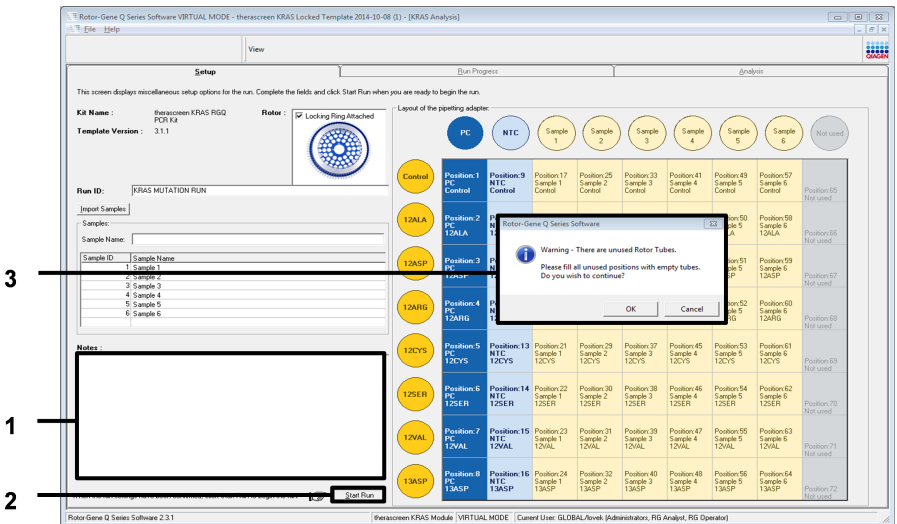
**Note:** A maximum of 7 samples can be added. The sample IDs (in the sample circles) will automatically be assigned from 1 to 7.

**Note:** Sample names with more than 8 characters may not be completely displayed in the Layout of the pipetting adapter panel.

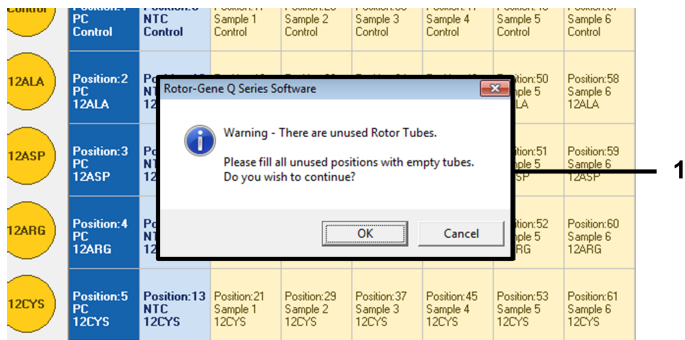
17. Repeat step 16 to enter the names of all additional samples.

**Note:** To edit a sample name, click the sample name in the sample list (4) and the selected sample will appear in the **Sample Name** field (3) above. Edit the sample name according to your local naming convention and press the **Return** key to update the name.

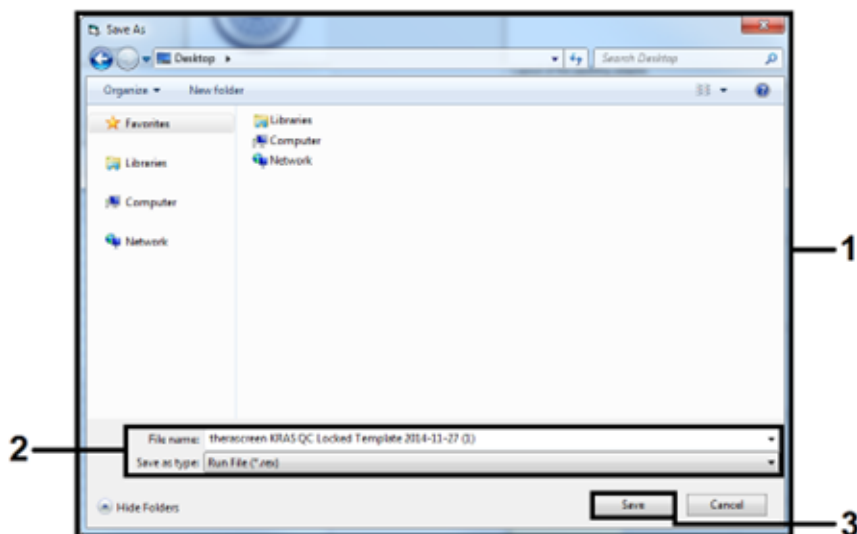
18. When all sample names have been entered, verify they are correct. Add any additional information in the **Notes** field (1 in the example below) if necessary and then click **Start Run** (2).



**Note:** If any rotor position is unused, a warning will appear (3 above and 1 in example below) to remind the user that all unused positions on the rotor must be filled with a capped, empty tube.

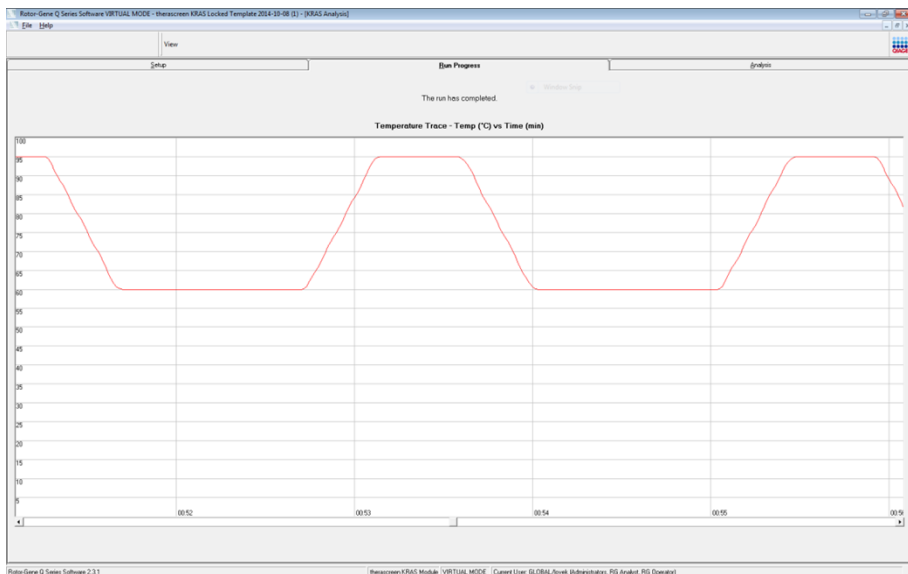


- 19. Check that all unused rotor positions are filled with a capped, empty tube and click **OK** to proceed.
- 20. A Save As window appears (1). Select an appropriate file name (2) and click **Save** (3) to save the PCR run as a \*.rex run file to the selected location.



21. The PCR run starts.

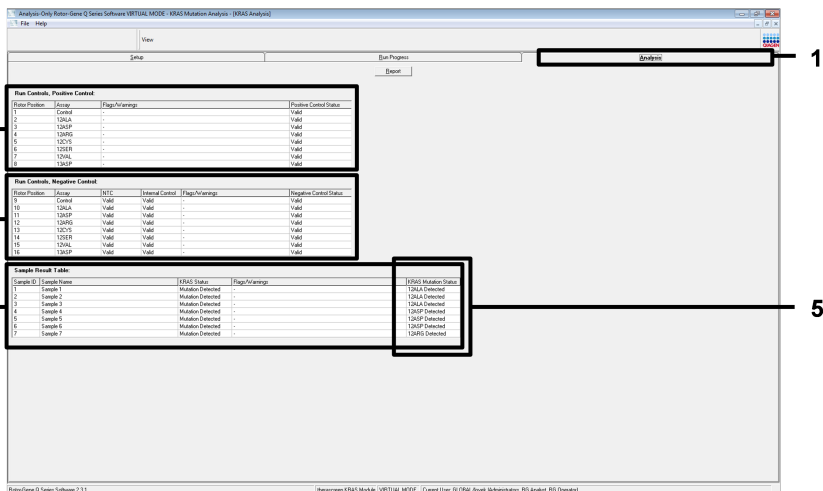
**Note:** When the run starts, the Run Progress tab will open automatically to show the temperature trace and remaining run time.



22. After the run is finished, the Analysis tab will open automatically.

**Note:** If the Analysis tab fails to open, click the **Analysis** tab (1).

**Note:** An explanation of the calculation method is presented in the "Analysis and mutation calls" on page 58.



23. Assay results are reported as follows:

- The **Run Controls, Positive Control** panel (2)

If the results are within acceptable range, the **Positive Control Status** will display "Valid"; otherwise an "Invalid" result will appear.

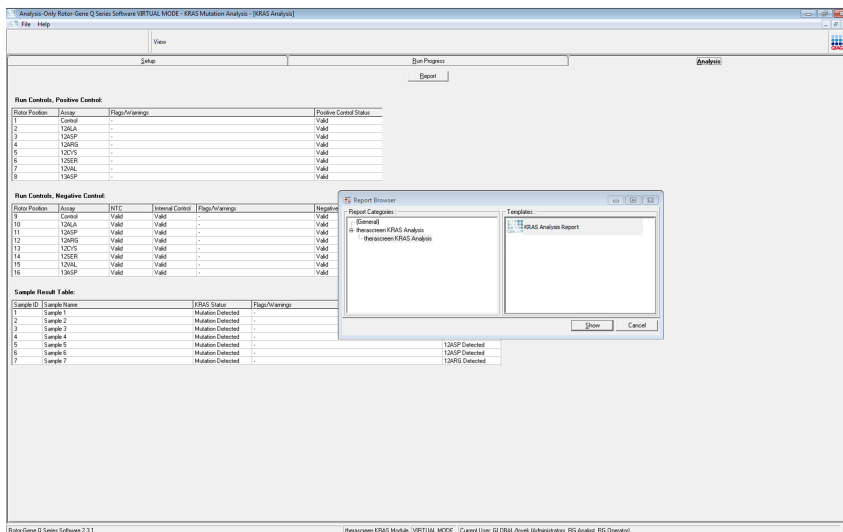
- The **Run Controls, Negative Control** panel (3)

If both the NTC and Internal Control results are within acceptable ranges, the **Negative Control Status** will display "Valid"; otherwise an "Invalid" result will appear.

- The **Sample Result Table** panel (4)

Specific mutations will be reported for the mutation positive samples under the **KRAS Mutation Status** column (5).

24. Click **Report** to generate report files. The Report Browser window will appear. Select **KRAS Analysis Report** under Templates, then click **Show**.



**Note:** Reports can be saved to an alternative location in Web Archives format by clicking the **Save As** button on the top left corner of each report.

**Note for NSCLC and CRC samples:** In order to avoid calling of a false G12C (12CYS) mutation result, sample(s) with the flags listed below must be interpreted as Invalid. For more information regarding flag interpretation refer to the interpretation recommendation actions in Table 11 on page 61 and Table 12 on page 63.

- SAMPLE\_INT\_CTRL\_EARLY\_CT
- SAMPLE\_POSITIVE\_AND\_INVALID
- SAMPLE\_INT\_CTRL\_FAIL
- MUTATION\_EARLY\_CT
- SAMPLE\_INVALID\_DATA

# Interpretation of Results

The analysis and mutation calls are performed automatically by the Rotor-Gene Q *therascreen* KRAS Assay Package once a run is completed. The following information explains how Rotor Gene Q *therascreen* KRAS Assay Package makes the analysis and mutation calls.

## Analysis and mutation calls

The PCR cycle at which the fluorescence from a particular reaction crosses a threshold value is defined as the  $C_T$  value.  $C_T$  values indicate the quantity of specific input DNA. Low  $C_T$  values indicate higher input DNA levels and high  $C_T$  values indicate lower input DNA levels. Reactions with a  $C_T$  value are classed as positive amplification.

The Rotor-Gene Q software interpolates fluorescence signals between any 2 recorded values. The  $C_T$  values can therefore be any real number (not limited to integers) within the range of 0–40.

For the *therascreen* KRAS RGQ PCR Kit, the threshold value is set at 0.05 relative fluorescence units. This value is configured in the Rotor-Gene Q *therascreen* KRAS Assay Package for both the green and yellow channels. The threshold value was defined during development of the *therascreen* KRAS RGQ PCR Kit.

A calculation is performed to determine the  $\Delta C_T$  value using the equation:

$$\Delta C_T = [\text{mutation assay } C_T \text{ value}] - [\text{control assay } C_T \text{ value}]$$

The run controls (positive control, NTC, and internal controls) are assessed to ensure that acceptable  $C_T$  values are met, and the reactions are performing correctly.

Sample  $\Delta C_T$  values are calculated as the difference between the mutation assay  $C_T$  and control assay  $C_T$  from the same sample. Samples are classed as mutation positive if they give a  $\Delta C_T$  less than or equal to the cutoff  $\Delta C_T$  value for that assay. Above this value, the sample may either contain less than the percentage of mutation able to be detected by the *therascreen* KRAS RGQ PCR Kit (beyond the limit of the assays), or the sample is mutation negative, which would be reported as "No Mutation Detected".

No amplification in mutation reactions will be scored as No Mutation Detected.  $\Delta C_T$  values calculated from background amplification are expected to be greater than the cutoff  $\Delta C_T$  values, and the sample will be classed as "No Mutation Detected".

The assay results will be displayed as "[mutation name] Detected", "No Mutation Detected", "Invalid", or, if a run control fails, "Run Control Failed". For the mutation-positive samples, specific mutations will be reported. Other possible results that may be displayed are discussed in "Protocol: DNA Sample Assessment" on page 28 and "Troubleshooting Guide" on page 66 of this Instructions for Use.

For interpretation of flags generated by the Rotor-Gene Q *therascreen* KRAS Assay Package, please refer to "Rotor-Gene Q *therascreen* KRAS Assay Package flags" below.

**Note:** Rarely, a tumor may contain more than one mutation. In such instances, the mutation yielding the lowest  $\Delta C_T$  value will be identified.

## Rotor-Gene Q *therascreen* KRAS Assay Package flags

Based on the specific intended use for CRC and NSCLC samples, there are specific actions associated with particular flags. Actions for flags for each indication are detailed in the following sections.

# Flags specific for both NSCLC and CRC

Table 10 lists the possible flags that may be generated by the Rotor-Gene Q *therascreen* KRAS Assay Package, the meaning of the flags, and actions to be taken.

**Table 10. Rotor-Gene Q *therascreen* KRAS Assay Package flags meanings and recommended actions**

Flag	Meaning	Action
PC_CTRL_ASSAY_FAIL	PCR run invalid — FAM C <sub>T</sub> out of range for positive control in control reaction	Repeat the entire PCR run.
PC_MUTATION_INVALID_DATA	PCR run invalid — Fluorescence data in positive control (mutation reaction mix) can't be interpreted	Repeat the entire PCR run.
NTC_INT_CTRL_FAIL	PCR run invalid — Internal control above range for negative control	Repeat the entire PCR run.
NTC_INT_CTRL_EARLY_CT	PCR run invalid — Internal control is below range for negative control	Repeat the entire PCR run.
NTC_INVALID_CT	PCR run invalid — FAM invalid (smaller than limit) for negative control	Repeat the entire PCR run.
NTC_INVALID_DATA	PCR run invalid — Fluorescence data in negative control can't be interpreted	Repeat the entire PCR run.
SAMPLE_CTRL_INVALID_DATA	Sample invalid — Fluorescence data in sample control can't be interpreted	Setup new PCR run to repeat the relevant sample(s).
SAMPLE_CTRL_HIGH_CONC	Sample Invalid — FAM C <sub>T</sub> too low in sample control	Dilute sample to increase control C <sub>T</sub> value. This dilution should be calculated on the assumption that diluting 1:1 with the water supplied in the kit will increase the C <sub>T</sub> by 1.0; once sample is diluted, setup new PCR run to repeat sample.

# Flags specific for NSCLC

Table 11 lists the possible flags that may be generated by the Rotor-Gene Q *therascreen* KRAS Assay Package, the meaning of the flags, and actions to be taken for NSCLC samples.

**Table 11. Rotor-Gene Q *therascreen* KRAS Assay Package flags meanings and recommended actions for NSCLC samples**

Flag	Meaning	Action
SAMPLE_INT_CTRL_FAIL	C <sub>T</sub> too high (or no C <sub>T</sub> ) for internal control (HEX), FAM channel mutation-negative	In order to avoid calling of a false G12C (12CYS) mutation result must be interpreted as Invalid. Dilute the remaining sample 1 in 8 with water from the tube marked DIL ensuring the final volume is greater than 40 µL (e.g., 10 µL of DNA and 70 µL of water from the tube marked DIL), set up a new PCR run to repeat the sample. If invalid on the repeat PCR run, extract the sample from fresh FFPE sections (2 sections). Set up a new PCR run to test fresh extraction. If invalid, dilute the remaining sample 1 in 8 with water from the tube marked DIL ensuring the final volume is greater than 40 µL, then test this dilution. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.
SAMPLE_INT_CTRL_EARLY_CT	Mutation tube invalid — C <sub>T</sub> HEX too low for sample (internal control)	Setup new PCR run to repeat sample. If invalid on repeat PCR run, extract the sample from fresh FFPE sections (2 sections). Setup a new PCR run to test fresh extraction. If invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.
SAMPLE_INVALID_DATA	Mutation tube invalid — Fluorescence data in internal control can't be interpreted	Setup new PCR run to repeat sample. If invalid on repeat PCR run, extract the sample from fresh FFPE sections (2 sections). Setup a new PCR run to test fresh extraction. If invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.

**Table 11. Rotor-Gene Q thetascreen KRAS Assay Package flags meanings and recommended actions for NSCLC samples (continued)**

Flag	Meaning	Action
MUTATION_EARLY_CT	Mutation tube invalid — C <sub>T</sub> FAM too low for sample.	Setup new PCR run to repeat sample. If invalid on repeat PCR run, extract the sample from fresh FFPE sections (2 sections). Setup a new PCR run to test fresh extraction. If invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.
SAMPLE_POSITIVE_AND_INVALID	One or more mutations for a sample are valid and positive; at the same time one or more mutations for the same sample are invalid.	Setup new PCR run to repeat sample. If invalid on repeat PCR run, extract the sample from fresh FFPE sections (2 sections). Setup a new PCR run to test fresh extraction. If invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.
SAMPLE_CTRL_FAIL	Sample invalid — FAM C <sub>T</sub> too high in sample control reaction	Setup new PCR run to repeat sample. If invalid on repeat PCR run, extract the sample from fresh FFPE sections (2 sections). Setup a new PCR run to test fresh extraction. If invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.

# Flags specific for CRC

Table 12 lists the possible flags that may be generated by the Rotor-Gene Q *therascreen* KRAS Assay Package, the meaning of the flags, and actions to be taken for CRC samples.

**Table 12. Rotor-Gene Q *therascreen* KRAS Assay Package flags meanings and recommended actions for CRC samples**

Flag	Meaning	Action
SAMPLE_CTRL_FAIL	Sample invalid — FAM CT too high in sample control reaction	<p>Setup new PCR run to repeat sample.</p> <p>If invalid on repeat PCR run, repeat extraction (≥ 1 sections) based on the guidance of the total tumour area to be at least 4 mm<sup>2</sup>, use sections with &gt;20% tumor content by area for extraction (without macrodissection). For sections that are ≤20% tumor content by area, macrodissect one or more sections ensure total tumor area to at least 4 mm<sup>2</sup>.</p> <p>Setup a new PCR run to test fresh extraction, if invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.</p>
SAMPLE_INT_CTRL_FAIL	C <sub>T</sub> too high (or no C <sub>T</sub> ) for internal control (HEX), FAM channel mutation-negative	<p>If the sample given valid status -No action.</p> <p>If sample is given invalid status, setup a new PCR run to repeat sample.</p> <p>If invalid on repeat PCR run, repeat extraction (≥ 1 sections) based on the guidance of the total tumor area to be at least 4 mm<sup>2</sup>, use sections with &gt;20% tumor content by area for extraction (without macrodissection). For sections that are ≤20% tumour content by area, macrodissect one or more sections ensure total tumor area to at least 4 mm<sup>2</sup></p> <p>Setup a new PCR run to test fresh extraction, if invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.</p>

**Table 12. Rotor-Gene Q thetascreen KRAS Assay Package flags meanings and recommended actions for CRC samples (continued)**

Flag	Meaning	Action
SAMPLE_INT_CTRL_ EARLY_CT	Mutation tube invalid — C <sub>T</sub> HEX too low for sample (internal control)	<p>If sample given valid status — No action.</p> <p>If sample is given invalid status, setup new PCR run to repeat sample.</p> <p>If invalid on repeat PCR run, repeat extraction (≥ 1 sections) based on the guidance of the total tumor area to be at least 4 mm<sup>2</sup>, use sections with &gt;20% tumor content by area for extraction (without macrodissection). For sections that are ≤20% tumour content by area, macrodissect one or more sections ensure total tumor area to at least 4 mm<sup>2</sup>.</p> <p>Setup a new PCR run to test fresh extraction, if invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.</p>
SAMPLE_INVALID_ DATA	Mutation tube invalid — Fluorescence data in internal control can't be interpreted	<p>If sample given valid status — No action. If sample is given invalid status, setup new PCR run to repeat sample.</p> <p>If invalid on repeat PCR run, repeat extraction (≥ 1 sections) based on the guidance of the total tumor area to be at least 4 mm<sup>2</sup>, use sections with &gt;20% tumor content by area for extraction (without macrodissection). For sections that are ≤20% tumor content by area, macrodissect one or more sections ensure total tumor area to at least 4 mm<sup>2</sup>.</p> <p>Setup a new PCR run to test fresh extraction, if invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.</p>

**Table 12. Rotor-Gene Q thetascreen KRAS Assay Package flags meanings and recommended actions for CRC samples (continued)**

Flag	Meaning	Action
MUTATION_EARLY_CT	Mutation tube invalid — C <sub>T</sub> FAM too low for sample.	If sample given valid status — No action. If sample given invalid status, setup new PCR run to repeat sample. If invalid on repeat PCR run, repeat extraction (≥ 1 sections) based on the guidance of the total tumor area to be at least 4 mm <sup>2</sup> , use sections with >20% tumor content by area for extraction (without macrodissection). For sections that are ≤20% tumor content by area, macrodissect one or more sections ensure total tumor area to at least 4 mm <sup>2</sup> . Setup a new PCR run to test fresh extraction, if invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.
SAMPLE_POSITIVE_AND_INVALID	One or more mutations for a sample are valid and positive; at the same time one or more mutations for the same sample are invalid	Setup new PCR run to repeat sample. If invalid on repeat PCR run, repeat extraction (≥ 1 sections) based on the guidance of the total tumor area to be at least 4 mm <sup>2</sup> , use sections with >20% tumor content by area for extraction (without macrodissection). For sections that are ≤20% tumor content by area, macrodissect one or more sections ensure total tumor area to at least 4 mm <sup>2</sup> . Setup a new PCR run to test fresh extraction, if invalid, set up a new PCR run to retest re-extracted sample. If the sample does not give a valid result after this run, the sample is given an indeterminate mutation status and no further testing should be carried out.

# Troubleshooting Guide

This troubleshooting guide may be helpful in solving any problems that may arise. For more information, see also the Frequently Asked Questions page at our Technical Support Center: [www.qiagen.com/FAQ/FAQList.aspx](http://www.qiagen.com/FAQ/FAQList.aspx) (for contact information, visit [www.qiagen.com](http://www.qiagen.com)).

## Comments and suggestions

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### Invalid results

- |   |  |
|---|--|
| a. The storage conditions for one or more components did not comply with the instructions given in "Reagent Storage and Handling" on page 20. | Check the storage conditions and the expiration date (see the label) of the reagents and use a new kit, if necessary.                                      |
| b. The <i>therascreen</i> KRAS RGQ PCR Kit has expired.   | Check the storage conditions and the expiration date (see the kit label) of the reagents and, if necessary, use a new <i>therascreen</i> KRAS RGQ PCR Kit. |

### NTC samples show positive results in the FAM channel

- |   |   |
|---|---|
| Contamination occurred during preparation of the PCR. | Repeat the PCR with new reagents in replicates.<br>If possible, close the PCR tubes directly after addition of the sample to be tested.<br>Make sure that work space and instruments are decontaminated at regular intervals. |
|---|---|

# Quality Control

In accordance with QIAGEN's ISO-certified Quality Management System, each lot of *therascreen* KRAS RGQ PCR Kit is tested against predetermined specifications to ensure consistent product quality.

# Contraindication

There are no known contraindications.

# Limitations

The test is designed to detect 7 mutations in codons 12 and 13 of the *KRAS* gene. Samples with results reported as No Mutation Detected may harbor *KRAS* mutations not detected by the assay (e.g., 13CYS).

Detection of mutations is dependent on sample integrity and the amount of amplifiable DNA present in the specimen. The procedure should be repeated in the event that the initial assessment of the DNA in the sample indicates that the quantity is either not sufficient or too high for *KRAS* mutation analysis.

The *therascreen* KRAS RGQ PCR Kit is used in a polymerase chain reaction (PCR) procedure. As with all PCR procedures, samples may be contaminated by external sources of DNA in the test environment and the DNA in the positive control. Use caution to avoid contamination of samples and reaction mix reagents.

The *therascreen* KRAS RGQ PCR Kit is not to be used for diagnosis of any disease.

For testing samples to determine eligibility for, LUMAKRAS (sotorasib) or Krazati (adagrasib), the *therascreen* KRAS RGQ PCR Kit is intended to identify the *KRAS* G12C mutation.

The test has been designed such that each mutant reaction is most sensitive for the specific mutation being measured. However, in samples where a mutation is detected, cross reactivity may occur with other mutation reactions. If more than one mutant reaction is positive, the result is the one with the lowest  $\Delta C_T$  result.

The *therascreen* KRAS RGQ PCR Kit is only validated for FFPE in CRC tissue and NSCLC tissue.

The *therascreen* KRAS RGQ PCR Kit is only validated for use with the QIAamp DSP DNA FFPE Tissue Kit. Only the Rotor-Gene Q MDx (US) instrument has been validated for use with the *therascreen* KRAS RGQ PCR Kit.

# Performance Characteristics for CRC Specimens

## Analytical performance

The specific performance characteristics of the *therascreen* KRAS RGQ PCR Kit were determined by studies involving FFPE tissue samples collected from CRC patients and 8 FFPE human cell lines of which 7 harbor known *KRAS* mutations detected by the assay, and 1 *KRAS* wild-type (i.e., no mutations at codon 12 and 13). Mutation status of samples was confirmed by bi-directional Sanger sequencing.

## Cutoff

To establish the cut-offs for the assay, 220 FFPE samples were tested using a method following guidance in NCCLS EP17-A (21). The control reaction  $C_T$  range was established as 21.92 to 32.00. The cut-off values, which are based on the  $C_t$  of the control reaction subtracted from the  $C_t$  of the mutant reactions ( $\Delta C_t$ ) are shown in Table 13.

**Table 13. Established cutoff values for each mutation assay**

Mutation assay	12ALA	12ASP	12ARG	12CYS	12SER	12VAL	13ASP
Cutoff ( $\leq \Delta C_T$ )	8.0	6.6	8.0	8.0	8.0	7.5	7.5

## Limit of blank

To assess performance of the *therascreen* KRAS RGQ PCR Kit in the absence of mutant positive template, and to ensure that a blank sample does not generate an analytical signal that may indicate a low concentration of mutation, samples with no template were evaluated. The results demonstrated no detectable control or mutant  $C_T$  values in any of the mutation or control reaction tubes (internal control  $C_T$  values were all valid).

## Comparison to analytical reference method

Two studies were conducted to demonstrate the concordance in mutation status of CRC samples tested with the *therascreen* KRAS RGQ PCR Kit relative to bidirectional sequencing. In the first study, 350 procured tumor samples from CRC patients were selected based on a set of baseline clinical, demographic and tumor specimen characteristics. Using a statistical random sampling technique, 150 samples of unknown mutation status were chosen for evaluation. These (150) FFPE samples were tested and subsequently analyzed in this study using statistical measures of agreement/disagreement from the CLSI EP12-A2 Guidance (22). A total of 137 of the FFPE samples returned valid results for both the *therascreen* KRAS RGQ PCR Kit and bidirectional sequencing.

The results demonstrated that the *therascreen* KRAS RGQ PCR Kit reported 2 samples as negative, 1 of which bidirectional sequencing indicated to be positive for 12ASP and the other indicated by bidirectional sequencing to be 13ASP. In contrast, 3 samples were reported as having a KRAS mutation by the *therascreen* KRAS RGQ PCR Kit which were not reported as positive by bidirectional sequencing. In addition, 1 sample identified as 12ARG by the *therascreen* KRAS RGQ PCR Kit was determined to be 12ASP by bidirectional sequencing. There were 5 samples determined to be mutation negative by bidirectional sequencing that were either indeterminate (3 samples) or invalid (2 samples) by the *therascreen* KRAS RGQ PCR Kit (data not shown). One sample that was indeterminate by Sanger bidirectional sequencing was determined to be 12SER by the *therascreen* KRAS RGQ PCR Kit (data not shown).

The results demonstrate a positive percentage agreement (PPA) of 96.3%, a negative percentage agreement (NPA) of 96.3%, and an overall percentage agreement (OPA) of 96.4%. The overall results, excluding 6 failed Sanger samples, are shown with the respective 95% confidence interval (CI) in Table 14.

Table 14. Analysis of agreement

Measurement of agreement	Frequency (%)	95% Confidence Interval (CI)
Overall percentage agreement	132/137 (96.35)	92.69–98.21
Percentage positive agreement	52/54 (96.30)	89.41–98.77
Percentage negative agreement	80/83 (96.39)	91.30–98.55

Table 15 shows details of the agreement between the *therascreen* KRAS RGQ PCR Kit and bidirectional sequencing.

Table 15. *therascreen* KRAS RGQ PCR Kit vs. bi-directional Sanger sequencing

Mutation call by bi-directional sequencing										
		Negative	12ALA	12ARG	12ASP	12CYS	12SER	12VAL	13ASP	Total
therascreen KRAS RGQ PCR Kit call	Negative	80	–	–	1	–	–	–	1	82
	12ALA	–	3	–	–	–	–	–	–	3
	12ARG	–	–	–	1	–	–	–	–	1
	12ASP	–	–	–	20	–	–	–	–	20
	12CYS	–	–	–	–	3	–	–	–	3
	12SER	–	–	–	–	–	–	–	–	0
	12VAL	2	–	–	–	–	–	14	–	16
	13ASP	1	–	–	–	–	–	–	11	12
	Total	83	3	0	22	3	0	14	12	137

A second unique set of samples was evaluated to supplement the data from the first study. A set of 271 CRC FFPE samples was procured; 250 of unknown mutation status and 21 samples of known mutation status to enrich for rare mutations were compared to Sanger bidirectional sequencing as described above.

A total of 13 (~5%) samples required macrodissection for *therascreen* KRAS RGQ PCR Kit evaluation. Out of the 271 samples with bidirectional sequencing results, 24 of the samples were indeterminate by the *therascreen* KRAS RGQ PCR Kit (failed control C<sub>T</sub> range; data not shown). Concordance analysis was carried out on 247 samples with both valid bidirectional and *therascreen* KRAS RGQ PCR Kit results. There were 9 discordant samples. One sample from the 247 samples had a mutation positive result with bidirectional sequencing but a “No Mutation Detected” result with the *therascreen* KRAS RGQ PCR Kit. Eight samples were shown to have a positive result with the *therascreen* KRAS RGQ PCR Kit but a negative result with bidirectional sequencing. Overall, agreement was 96.4%. The data supports the accurate performance of the *therascreen* KRAS RGQ PCR Kit (Table 16 and Table 17).

**Table 16. Analysis of agreement (second study)**

Measurement of agreement	Frequency (%)	95% Confidence Interval (CI)
Overall percentage agreement	238/247 (96.36)	93.73–98.09
Percentage positive agreement	106/107 (99.07)	95.64–99.95
Percentage negative agreement	132/140 (94.29)	89.93–97.13

Table 17 shows details of the agreement between the *therascreen* KRAS RGQ PCR Kit and bidirectional sequencing in the second study.

Table 17. *therascreen* KRAS RGQ PCR Kit vs. bi-directional Sanger sequencing (second study)

		Mutation call by bi-directional sequencing								
		Negative	12ALA	12ARG	12ASP	12CYS	12SER	12VAL	13ASP	Total
KRAS Kit call	Negative	132	–	–	–	–	1	–	–	133
	Positive 12ALA	–	10	–	–	–	–	–	–	10
	Positive 12ARG	5	–	5	–	–	–	–	–	10
	Positive 12ASP	–	–	–	31	–	–	–	–	31
	Positive 12CYS	1	–	–	–	11	–	–	–	12
	Positive 12SER	2	–	–	–	–	13	–	–	13
	Positive 12VAL	5	–	–	–	–	–	25	–	27
	Positive 13ASP	–	–	–	–	–	–	–	11	11
Total		140	10	5	31	11	14	25	11	247

Limit of detection (LOD)

The working range for the *therascreen* KRAS RGQ PCR Kit is based on the amount of amplifiable DNA in the specimen as determined by the control reaction C<sub>T</sub> value. The stated input range for the assay is defined by the control C<sub>T</sub> prespecified range of 21.92 to 32.00. The LOD is the minimum percentage of mutant DNA that can be detected in a background of wild-type when the total amplifiable DNA is within the stated input range and still below the threshold cut-off ΔC<sub>T</sub> value.

A study was conducted to determine the LOD of each of the 7 mutation-specific reactions incorporated in the *therascreen* KRAS RGQ PCR Kit. For the *therascreen* KRAS RGQ PCR Kit, the limit of detecting mutant DNA in a background of wild-type DNA is defined as the lowest dilution factor at which 95% of the test replicates for each mutation positive sample were determined to be positive. Eight FFPE cell lines; 7 with known mutant DNA content and 1 wild type were used for this evaluation.

The proportion of mutant in total amplifiable DNA (percentage mutant DNA) was determined previously using a bidirectional Sanger sequencing method from unfixed cells, followed by relative peak analysis. In the case of 3 cell lines, the mutant content was 100% (i.e., the cell line DNA was homozygous mutant). The other cell lines were of mixed zygosity. Multiple DNA extractions from each sample were pooled to generate DNA stocks. The DNA stocks were then normalized to achieve target control reaction  $C_T$  values. Normalized mutant DNA extracts were diluted with normalized wild-type DNA extract to create a dilution series of extracts containing the same level of total amplifiable DNA but different levels of mutant DNA. Serial dilutions were then generated from these samples and run in multiple replicates.

The first dilution series was created for the mid-range control reaction  $C_T$  value (approximately 26). Nine replicates per dilution were tested. The percentage of correct calls as a function of the dilution for each mutant reaction is shown in Table 18. Highlighted boxes indicate the percentage in which greater than 95% of the replicates produced correct calls.

Table 18. Percentage of correct calls as a function of the dilution for each mutation reaction

Mutation dilution (%)	Correct calls (%)						
	12ALA	12ASP	12ARG	12CYS	12SER	12VAL	13ASP
0.78	100	0	33.3	55.6	22.2	66.7	0
1.56	100	33.3	100	100	88.9	100	0
3.13	100	77.8	100	100	100	100	66.7

Table 18. Percentage of correct calls as a function of the dilution for each mutation reaction (continued)

Mutation dilution (%)	Correct calls (%)						
	12ALA	12ASP	12ARG	12CYS	12SER	12VAL	13ASP
6.25	100	100	100	100	100	100	100
12.5	100	100	100	100	100	100	100
25.0	100	100	100	100	100	100	100
50.0	100*	100	100	100	100	100	100

\* Mutation dilution for this sample was 40.0%.

The results of the first dilution series were used to generate dilutions for the confirmation of LOD values using narrower, reaction-specific ranges of percentage mutation dilutions at both low and high levels within the input range of the assay. For the high dilution series, 12 replicates of each were evaluated. The percentage of correct calls as a function of dilution for the high dilution series (target values approximately C<sub>T</sub> 23–24) is shown in Table 19. Highlighted boxes indicate the percentage in which greater than 95% of the replicates produced correct calls.

Table 19. Percentage of correct calls as a function of dilution for the high dilution series

Mutation	Mutation dilution high (%)					
12ALA	0.13	0.27	0.54	1.08	2.15	4.30
Correct calls (%)	0	0	91.7	100	100	100
12ASP	0.56	1.13	2.25	4.50	9.00	18.00*
Correct calls (%)	0	8.3	3.33	83.3	100	100
12ARG	0.16	0.33	0.65	1.30	2.60	5.20
Correct calls (%)	0	0	8.3	100	100	100
12CYS	0.12	0.24	0.49	0.98	1.95	3.90
Correct calls (%)	0	0	8.3	83.3	100	100

**Table 19. Percentage of correct calls as a function of dilution for the high dilution series (continued)**

Mutation	Mutation dilution high (%)					
12SER	0.31	0.63	1.25	2.50	5.00	10.00
Correct calls (%)	0	0	33.3	66.7	100	100
12VAL	0.17	0.34	0.69	1.38	2.75	5.50
Correct calls (%)	0	0	16.7	100	100	100
13ASP	0.63	1.25	2.50	5.0	10.0	20.0
Correct calls (%)	0	0	0	100	100	100

\* The number of valid replicates was 11.

For the low series, 24 replicates were evaluated per dilution, except where indicated. The percentage of correct calls as a function of dilution for the low dilution series (target approximately C<sub>T</sub> value 31) is shown in Table 20. Highlighted boxes indicate the percentage in which greater than 95% of the replicates produced correct calls.

**Table 20. Percentage of correct calls as a function of dilution for the low dilution series**

Mutation	Mutation dilution high (%)						
12ALA	0.27	0.54	1.08	2.15	4.30	8.60	12.90
Correct calls (%)	12.5	20.8	33.3	83.3	100	100	100
12ASP	0.56	1.13	2.25	4.50	9.00	18.0	27.0
Correct calls (%)	0	8.3	3.33	83.3	100	100	100
12ARG	0.33	0.65	1.30	2.60*	5.20	10.40	15.60
Correct calls (%)	8.3	4.2	29.2	52.2	95.8	100	100
12CYS	0.24	0.49	0.98	1.95	3.90	7.80	11.70
Correct calls (%)	8.3	4.2	20.9	54.2	83.3	100	100
12SER	0.63	1.25	2.50	5.00	10.0	20.0	30.0
Correct calls (%)	0	0	8.3	33.3	70.9	83.3	100
12VAL†	0.34	0.69	1.38	2.75	5.50	11.0	16.50
Correct calls (%)	4.3	16.7	46.7	75.0	100	100	100

Table 20. Percentage of correct calls as a function of dilution for the low dilution series (continued)

Mutation	Mutation dilution high (%)						
13ASP	0.63	1.25	2.50	5.0	10.0	20.0	30.0
Correct calls (%)	0	4.2	8.3	33.3	70.8	100	100

\* The number of valid replicates for 12ARG at 2.60 dilution was 23.

† The numbers of valid replicates in the series were 23, 24, 15, 16, 13, 12 and 19 for 12VAL.

Logistic regression models were applied to each assay individually for the low and high input DNA datasets. In these models, the response variable was the binary output of mutation detected (detect = 1) and mutation not detected (detect = 0), the continuous explanatory variable was log2 % mutation dilution. The LODs were calculated as the percent mutation dilution which gave a predicted probability of detection of 0.95. The LODs determined from the dilution series beginning with either the low or high CT values are shown in Table 21.

Table 21. Logistics regression data (LODs) for low and high C<sub>T</sub> dilutions series

Assay	Low	High
12ALA	4.25	0.56
12ASP	10.23	6.43
12ARG	7.27	0.87
12CYS	6.90	1.21
12SER	25.75	4.20
12VAL	5.17	0.90
13ASP	18.83	4.16

The final LOD claims using FFPE cell lines when the input C<sub>T</sub> value is between approximately 22 and 27 C<sub>T</sub> are shown in Table 22. At the lower end of the C<sub>T</sub> input range, the sensitivity of the assay decreases. The amount of input DNA may not contain sufficient copies to support the same percentage ratios of wild-type to mutant DNA observed within the high- and mid-points of the working range.

Table 22. LoD values for each mutations using FFPE cell lines

Assay	LoD C <sub>95</sub> (percentage of mutant DNA in wild-type DNA)
12ALA	0.8
12ASP	6.4
12ARG	2.6
12CYS	1.5
12SER	5.6
12VAL	1.6
13ASP	6.4

## Effect of input DNA

When samples at different total DNA levels contain the same proportion of mutant DNA, it is expected that the measured  $\Delta C_t$  values will remain consistent over. The objective of the study was to demonstrate that the performance of the *therascreen* KRAS RGQ PCR Kit is consistent over the total DNA input (control C<sub>T</sub>) range of the assay. DNA extracted from 8 FFPE cell lines was used to prepare pools of DNA with the lowest achievable Control reaction C<sub>t</sub>. Concentrated DNA stocks were subsequently diluted to generate DNA spanning the working range (a total of 5 dilutions including the initial concentrated stock).

For each point within the working range, sufficient material was prepared to carry out 6 replicate tests. The dilution range for each mutation reaction and the mean  $\Delta C_t$  value obtained from the results are shown in Table 23. For each of the mutations detected by the *therascreen* KRAS RGQ PCR Kit, the  $\Delta C_T$  values measured at different total DNA input levels spanning the working range of the assay passed the pre-set acceptance criteria for the study. Although there is a slight increase in  $\Delta C_T$  as DNA input increases, overall, the  $\Delta C_T$  values were consistent across the working range of the *therascreen* KRAS RGQ PCR Kit within the prespecified acceptance criteria.

**Table 23. Effect of DNA input on  $\Delta C_t$  values across the input control reaction  $C_t$  range — FFPE cell lines**

Assay	$\Delta C_t$				
	Dilution 1 ~20–21 $C_t$	Dilution 2 ~23–24 $C_t$	Dilution 3 ~26–27 $C_t$	Dilution 4 ~29–30 $C_t$	Dilution 5 ~32–33 $C_t$
12ALA	1.56	1.25	1.16	1.14	1.27
12ARG	2.46	2.18	2.11	2.11	1.75
12ASP*	1.18	0.63	1.08	0.94	1.06
12CYS	0.29	0.25	0.15	0.26	–0.1
12SER	2.91	2.21	2.15	2.15	2.08
12VAL	0.98	0.71	0.58	0.81	0.67
13ASP	3.57	2.84	2.54	2.46	2.62

\* The total number of replicates for 12ASP was 27.

## Linearity/amplification efficiency as a function of DNA input

The linearity and amplification efficiency of PCR for each mutation reaction, relative to the control reaction, across the working range of the *therascreen* KRAS RGQ PCR Kit was demonstrated. Amplification efficiency was calculated for each of the mutation reactions and the control reaction as  $[2^{(-1/\text{slope})}] - 1$ . The amplification efficiency of the control compared

to the mutant reaction indicates that the  $\Delta C_T$ , and thus mutation call, is consistent across the working range of the assay. The largest difference in the amplification efficiencies between the control reaction and a mutant reaction was observed for the 13ASP assay with a mean difference in efficiencies of approximately 14.5%. A summary of the data is shown in Table 24.

Table 24. Summary of the data on amplification efficiency (function of DNA input)

Sample		Intercept	Intercept stand- and error	Calculated slope	Standard error (slope)	Lower 2-sided 95% con- fidence limit (slope)	Upper 2-sided 95% con- fidence limit (slope)	Amplification efficiency	Difference in amplification efficiencies
12ALA	Control C <sub>T</sub>	21.060	0.060	-1.008	0.007	-1.023	-0.993	0.989	0.03
	12ALA C <sub>T</sub>	22.476	0.103	-0.987	0.013	-1.013	-0.961	1.019	
12ASP	Control C <sub>T</sub>	20.825	0.083	-1.035	0.01	-1.056	-1.014	0.954	0.056
	12ASP C <sub>T</sub>	23.237	0.083	-0.993	0.011	-1.016	-0.97	1.01	
12ARG	Control C <sub>T</sub>	20.385	0.13	-1.013	0.16	-1.046	-0.98	0.982	-0.003
	12ARG C <sub>T</sub>	21.347	0.065	-1.015	0.008	-1.032	-0.999	0.979	
12CYS	Control C <sub>T</sub>	23.437	0.063	-0.981	0.01	-1.003	-0.96	1.026	0.032
	12CYS C <sub>T</sub>	24.289	0.039	-0.961	0.006	-0.974	-0.947	1.058	
12SER	Control C <sub>T</sub>	22.568	0.050	-1.003	0.008	-1.02	-0.986	0.996	0.105
	12SER C <sub>T</sub>	25.212	0.087	-0.934	0.014	-0.963	-0.904	1.101	
12VAL	Control C <sub>T</sub>	21.208	0.047	-0.995	0.006	-1.007	-0.983	1.007	0.033
	12VAL C <sub>T</sub>	21.532	0.043	-0.972	0.005	-0.983	-0.961	1.04	
13ASP	Control C <sub>T</sub>	23.207	0.056	-1.001	0.009	-1.02	-0.982	0.999	0.145
	12ASP C <sub>T</sub>	26.466	0.106	-0.909	0.017	-0.945	-0.873	1.144	

## Linearity/amplification efficiency as a function of percent mutation

The objective of this study was to evaluate the effect of serially diluted mutant positive sample on amplification efficiency, across the working range of the *therascreen* KRAS RGQ PCR Kit, beginning with input levels of  $C_T$  at approximately 22–23  $C_T$ . DNA extracts from FFPE cell lines were initially assessed by OD readings prior to carrying out PCR with the *therascreen* KRAS RGQ PCR Kit. DNA stocks were then prepared to a control reaction  $C_T$  corresponding to ~23  $C_T$ . The stocks were diluted serially 2-fold each time using wild-type DNA to maintain the total wild-type DNA constant while varying the percentage mutant DNA in the template. Thus, each of the templates generated had the same absolute quantity and concentration of DNA but differing ratios of wild-type to mutant DNA.

Pools of DNA sufficient for 6 replicates per mutation were prepared.  $C_T$  and  $\Delta C_T$  data for each mutation at each dilution point were calculated. The mutation reaction  $C_T$  values were plotted and the efficiencies were calculated; the control reaction  $C_T$  values were consistent over the dilution series of each mutation. For each sample where the control reaction  $C_T$  value fell within the specified range (21.92–32.00),  $\Delta C_T$  values were calculated. A linear regression model was fitted with mutation reaction  $C_T$  versus  $\log_2$  DNA input dilution. The slope and 95% confidence intervals were reported.

The study showed the dilution of mutations in a background of a constant concentration of wild type DNA resulted in amplification efficiencies that did not vary significantly outside the values determined in the above linearity study with the amplification efficiencies differing by less than  $\pm 10\%$ . A summary of the data is shown in Table 25.

Table 25. Summary of the data on amplification efficiency (function of percent mutation)

Sample	Intercept	Intercept standard error	Calculated slope	Standard error (slope)	Lower two-sided 95%	Upper two-sided 95% confidence limit (slope)	Amplification efficiency
12ALA	23.540	0.025	-0.968	0.010	-0.989	-0.947	<b>1.047</b>
12ASP	24.804	0.054	-1.030	0.022	-1.075	-0.985	<b>0.960</b>
12ARG	24.226	0.028	-1.008	0.11	-1.031	-0.984	<b>0.990</b>
12CYS	24.354	0.027	-0.981	0.011	-1.003	-0.959	<b>1.027</b>
12SER	25.376	0.054	-0.892	0.022	-0.937	-0.847	<b>1.174</b>
12VAL	22.703	0.035	-1.021	0.014	-1.050	-0.992	<b>0.972</b>
13ASP	27.555	0.057	-0.810	0.023	-0.857	-0.763	<b>1.353</b>

### Interfering substances

The objective of this study was to evaluate the impact of potentially interfering substances on the performance of the *therascreen* KRAS RGQ PCR Kit. This was performed by analyzing the impact of each substance, by means of spiking experiments at two concentrations, on the  $\Delta C_T$  values and mutation status of test samples. The concentrations are shown in Table 26.

**Table 26. Amount of interfering substances tested in each assay**

Interfering substance	Actual high amount [µL/200 µL eluate]	Actual low amount [µL/200 µL eluate]
Paraffin wax (in xylene)	$2.00 \times 10^{-4}$	$5.00 \times 10^{-5}$
Xylene	$2.00 \times 10^{-4}$	$5.00 \times 10^{-5}$
Ethanol	$1.35 \times 10^{-3}$	$3.38 \times 10^{-4}$
Buffer ATL	$5.40 \times 10^{-4}$	$1.35 \times 10^{-4}$
Proteinase K	$1.32 \times 10^{-5}$	$3.30 \times 10^{-6}$
Buffer AL	$1.33 \times 10^{-3}$	$3.33 \times 10^{-5}$
Wash Buffer AW1	0.50	$1.25 \times 10^{-1}$
Wash Buffer AW2	5.00	1.25

None of the potentially interfering substances evaluated at the concentrations expected to be encountered in normal use impacts the ability of the *therascreen* KRAS RGQ PCR Kit to distinguish between mutation-positive and mutation-negative samples.

In addition to the interfering substances study, the potential effect of necrosis in clinical samples was assessed to determine if high levels of necrotic tissue in tumor samples impact the ability to generate valid data. From a total of 421 samples assessed as part of the Comparison to analytical reference method studies (see "Comparison to analytical reference method" on page 70), 29 samples had necrosis at a level >50% as determined by pathology review. Of these 29 samples, 28 returned valid results that were concordant to bi-directional Sanger sequencing. A single result was invalid due to insufficient DNA.

## Cross-contamination

The objective of this study was to determine the extent of cross-contamination potentially leading to false positive results between DNA samples using the *therascreen* KRAS RGQ PCR Kit. Potential sources of cross-contamination include:

- Sample extraction (e.g., scraping of slides)
- Pipetting of samples
- Closure (“capping”) of sample tubes
- Contamination of kit reagents during use
- Loading of assay tubes onto the Rotor-Gene Q MDx (US) instrument

For this study, FFPE standards were used: the wild-type standard and the 12ALA standard (since the 12ALA reaction is the reaction with the lowest LOD in the kit).

The study consisted of 10 PCR runs designed to investigate the potential for contamination both within and between Rotor-Gene Q MDx (US) instrument runs. In these test runs, tubes containing wild type DNA were used to test for contamination from mutant DNA.

The results of this study indicated no detectable contamination in any of the wild-type DNA extracts intended to detect cross-contamination.

## Exclusivity/cross-reactivity

The *therascreen* KRAS RGQ PCR Kit is comprised of 8 separate reactions; one single control reaction that detects a non-polymorphic region of the *KRAS* gene and 7 mutation-specific reactions. There is no reaction that specifically measures the wild-type *KRAS* sequence at codon 12 or 13. The *KRAS* “No Mutation Detected” result, (i.e., wild-type) is determined from the absence of any of the 7 mutations resulting in a positive mutation result. Therefore, it is necessary to demonstrate the amount of nonspecific amplification, or cross-reactivity that occurs in each reaction with excess amounts of *KRAS* wild-type DNA to ensure no false positive results occur. Similarly, nonspecific amplification of *KRAS* mutations which the reaction is not intended to detect is evaluated to demonstrate that the amount of cross-reactivity between mutant reactions does not result in erroneous mutation calls in the presence of excess amounts of mutant DNA. Since the DNA input for this assay is based on the control  $C_T$  range

(21.92 to 32.00), the highest concentration of DNA input is based on having a control  $C_T$  value of approximately 22. FFPE clinical samples were used for this evaluation, as well as FFPE cell line DNA.

Non-specific amplification/cross-reactivity: wild-type KRAS DNA

To address the amount of nonspecific amplification of wild-type DNA by reaction mixes designed to amplify specific mutations, 60 replicates of wild-type FFPE cell-line DNA or DNA extracted from CRC tumor tissue at the highest concentration of amplifiable DNA input level were evaluated using the *therascreen* KRAS RGQ PCR Kit. For DNA extracted from the FFPE cell line, the control  $C_T$  values were approximately 22–23. Control  $C_T$  values for three wild-type CRC samples were between 24 and 25. The results demonstrated that the  $\Delta C_T$  values exceeded the established cut-offs. The mean and lowest  $\Delta C_T$  values observed for each reaction is shown in Table 27.

Table 27. Lowest mean  $\Delta C_T$  observed for wild-type samples in mutant reactions

Mutant reaction	Cut-off	Lowest $\Delta C_T$ observed	Sample 1 $\Delta C_T$ mean (lowest)	Sample 2 $\Delta C_T$ mean (lowest)	Sample 3 $\Delta C_T$ mean (lowest)
12ALA	8	12.76	18.00 (11.40)	18.62 (11.50)	20.03 (19.36)
12ASP	6.6	10.35	10.90 (9.62)	10.34 (8.84)	10.68 (9.01)
12ARG	8	14.26	20.33 (12.94)	20.02 (13.20)	20.03 (19.36)
12CYS	8	13.66	20.62 (17.38)	20.29 (19.62)	20.03 (19.36)
12SER	8	11.97	17.26 (11.14)	17.90 (11.42)	18.05 (10.44)
12VAL	7.5	11.81	14.87 (11.46)	16.27 (11.50)	18.68 (11.36)
13ASP	7.5	10.94	12.35 (9.08)	13.68 (10.69)	14.82 (9.97)

Non-specific amplification/cross-reactivity: mutation positive KRAS DNA

Mutant samples that have a high concentration of input DNA were tested against all reaction mixes by preparing DNA samples from each of the FFPE cell lines so that the control reaction  $C_T$  corresponded to approximately 23. Six replicates of each mutation sample were evaluated. The percentage of mutation in the sample was governed by the percentage of mutant in the cell line DNA. The mean  $\Delta C_T$  values are presented in Table 28 demonstrates that there is cross reactivity between mutant reactions. The 12ALA mutation was amplified and generated  $\Delta C_T$  values below the  $\Delta C_T$  thresholds for the 12CYS, 12SER and 12VAL reactions. The 12VAL mutation was amplified and generated a  $\Delta C_T$  value below the  $\Delta C_T$  threshold for the 12ALA reaction.

In all cases the results demonstrate that the correct mutation was called with the matched mutation reaction (i.e., the smallest  $\Delta C_T$  value was the correct mutation call). All other test cases were either not detected or outside the  $\Delta C_T$  threshold.

Table 28.  $\Delta C_T$  cross-reactivity between mutation reactions using FFPE cell line DNA at the high input range

Mutant DNA	Cutoff	Assay $\Delta C_T$						
		12ALA	12ASP	12ARG	12CYS	12SER	12VAL	13ASP
12ALA	8	<b>1.42*</b>	12.66	–	5.81	2.78	6.31	13.21
12ASP	6.6	12.56	<b>2.42*</b>	–	–	13.44	11.21	13.55
12ARG	8	13.12	11.56	<b>1.12*</b>	11.42	–	13.43	12.66
12CYS	8	14.2	12.48	9.23	<b>0.98*</b>	–	7.96	12.88
12SER	8	–	13.39	13.31	–	<b>3.02*</b>	12.99	13.97
12VAL	7.5	6.83	–	–	–	13.38	<b>0.28*</b>	13.74
13ASP	7.5	–	13.29	13.89	–	–	14.36	<b>4.5*</b>

\*  $\Delta C_T$  values from matched reactions are shown in bold. Blank cells show no cross-reaction.

$\Delta C_T$  from cross-reactive reactions below the cut-off are highlighted.

## Repeatability and reproducibility

The precision of the *therascreen* KRAS RGQ PCR Kit was determined using a protocol incorporating aspects of CLSI EP12-A and EP5-A2 (22, 23). Clinical CRC samples were used for this evaluation. One wild-type and one sample for each mutation were tested with the *therascreen* KRAS RGQ PCR Kit, using 2 operators at each of 3 sites testing all samples and controls on 3 lots of *therascreen* KRAS RGQ PCR Kits, each day for 5 days, with 2 runs per day and with 2 replicates of each sample on each run. The  $C_T$  and  $\Delta C_T$  values obtained for each reaction in each sample were also analyzed by variance component analysis.

Reproducibility of the *therascreen* KRAS RGQ PCR Kit was demonstrated for low level mutant (3xLOD) and wild type samples, with at least 39/40 correct mutation calls for all assays across multiple lots, platforms and operators, for both within and between laboratory experiments. Estimates of variance demonstrated (1x standard deviation) using C50 and 3xLOD samples are listed in Table 29 and Table 30.

Table 29. Assay variance estimates

Assay	%CV for $\Delta C_T$		%CV for mutant $C_T$		%CV for control $C_T$		
	3xLOD	C50	3xLOD	C50	3xLOD	C50	WT
12ALA	13.14	8.32	1.87	2.02	0.97	1.12	1.12
12ARG	10.79	8.04	1.59	1.96	1.24	1.51	1.15
12ASP	12.86	5.87	1.11	1.00	0.90	0.90	1.04
12CYS	17.61	10.83	1.86	2.02	1.54	1.22	1.15
12SER	13.97	10.43	1.71	2.11	0.94	1.19	1.15
12VAL	9.66	15.47	1.52	1.65	1.11	3.74	1.26
13ASP	13.73	9.35	1.91	2.08	1.11	1.41	1.19

Table 30. Repeatability precision estimates

Assay	%CV for $\Delta C_t$		%CV for mutant $C_t$		%CV for control $C_t$		
	3xLOD	C50	3xLOD	C50	3xLOD	C50	WT
12ALA	10.71	7.51	1.69	1.76	0.77	0.90	0.79
12ARG	9.83	8.04	1.21	1.76	0.84	1.33	0.90
12ASP	10.16	4.08	0.93	0.89	0.80	0.76	0.76
12CYS	13.15	8.80	1.31	1.76	1.40	1.01	0.76
12SER	6.76	6.18	1.10	1.48	0.80	0.90	0.90
12VAL	9.21	15.32	1.40	1.42	0.91	3.49	0.94
13ASP	8.67	7.01	1.30	1.65	0.91	1.19	0.97

The estimated proportion of 3xLOD samples testing mutant and wild-type samples were reported overall and within each of the sites. For all assays and sample combinations, at least 79 out of 80 replicates gave the correct mutation call. The overall proportion of correct calls was 99.6% (1115/1120); 99.6% (558/560) for mutation positive (3xLOD) samples and 99.5% (557/560) for no-mutation detected (wild-type) samples (Table 31).

Table 31. Correct calls overall

Mutation	Correct calls	
	3xLOD samples	Wild-type samples (low)
12ALA	79/80	80/80
12ARG	80/80	79/80
12ASP	80/80	80/80
12CYS	79/80	80/80
12SER	80/80	79/80
12VAL	80/80	79/80
13ASP	80/80	80/80

# Sample handling variability

To assess sample handling variability as part of the *therascreen* KRAS RGQ PCR Kit process, 30 sequential 5 µm sections were cut from each of 10 FFPE CRC samples (3 wild-type and 1 per mutation). Sections were randomized to 1 of 3 testing sites so that each site received 10 sections per FFPE sample (100 sections total). Of the 300 DNA extractions tested, 298 samples were valid.

There was 99.33% concordance with respect to the *KRAS* mutation calls between the 3 sites. The variance of  $\Delta C_T$  values for each assay was estimated, and the contribution of between and within laboratory sources was estimated using an ANOVA variance components model. Variance for within test sites was highest for 12ASP (0.30). Variance between test sites was highest for 12SER (0.05). A comparison by site of mean  $\Delta C_T$  values with corresponding standard deviation (SD) for mutant and wild-type samples showed very close agreement for the results (Table 32 and Table 33). The results demonstrate the agreement of the DNA extraction procedure and sample processing in conjunction with the *therascreen* KRAS RGQ PCR Kit.

Table 32. Comparison by site of mean  $\Delta C_T$  (SD) values for mutant type samples

	$\Delta C_T$ (Standard deviation)						
	12ALA	12ARG	12ASP	12CYS	12SER	12VAL	13ASP
Site 1	2.44 (0.1)	2.62 (0.3)	3.03 (0.6)	2.24 (0.1)	2.34 (0.3)	2.51 (0.1)	3.93 (0.4)
Site 2	2.44 (0.2)	2.52 (0.4)	3.01 (0.7)	2.29 (0.2)	2.10 (0.4)	2.44 (0.5)	4.15 (0.7)
Site 3	2.67 (0.6)	2.52 (0.2)	3.07 (0.5)	2.29 (0.2)	2.74 (0.5)	2.56 (0.2)	3.95 (0.3)

Table 33. Comparison by site of mean  $\Delta C_T$  (SD) values for wild-type samples

	$\Delta C_T$ (Standard deviation)						
	12ALA	12ARG	12ASP	12CYS	12SER	12VAL	13ASP
Site 1	12.46 (0.3)	—*	10.37 (0.4)	—	11.84 (0.4)	12.36 (0.5)	11.11 (0.6)
Site 2	12.09 (0.6)	13.07 (0.2)	10.17 (0.5)	—	11.71 (0.7)	12.20 (0.6)	11.00 (0.9)
Site 3	12.07 (0.2)	—	10.61 (0.4)	—	11.94 (0.3)	12.28 (0.6)	11.82 (0.5)

\* Denotes a missing value, due to no breakthrough being observed.

### Lot interchangeability

The potential for lot-to-lot variability to impact the mutation detection was assessed. In this study, 3 lots of QIAamp DSP DNA FFPE Tissue Kit (FFPE extraction kit) and *therascreen* KRAS RGQ PCR Kit with each lot of FFPE extraction kit were evaluated. DNA was extracted from FFPE cell lines with 3 lots of FFPE extraction kit to yield DNA samples with target control  $C_T$  values of approximately 23, 26, and 31. These  $C_T$  values were selected to span the defined working range of total DNA input level for the *therascreen* KRAS RGQ PCR Kit (control  $C_T$  within 21.92–32.00). Six replicate extractions at each of the target  $C_T$  values were tested by each of the 3 independent *therascreen* KRAS RGQ PCR Kit lots. The  $\Delta C_T$  values and mutation calls were collected for all test samples. The predefined study objectives were met with the correct mutation call observed in 100% of valid tests, confirming that sample mutation calling is not affected by using different lots of FFPE extraction kits and/or *therascreen* KRAS RGQ PCR Kits.

# Performance Characteristics for NSCLC Specimens

## Analytical performance

### Limit of Detection (LoD)

The LOD values for the *therascreen* KRAS RGQ PCR Kit were previously determined using DNA extracted from FFPE Cell Lines. The objective for this study was to re-verify that the LOD of each of the mutation assays with NSCLC specimens is below or equal to 10% mutation content in the background of wild type DNA, when concentration of DNA is not a limiting factor. The LOD re-verification was performed using a mixture of Cell Line samples (12ALA, 12SER and 13ASP) and clinical FFPE NSCLC samples (12ASP, 12ARG, 12CYS, and 12VAL). In a follow up study, clinical samples representing 12ALA, 12SER and 13ASP mutations were used. DNA extracted from mutation positive test samples, and wild type samples (to be used as diluents) were normalized to a medium DNA input level. The mutation positive samples were then diluted to low levels of mutant DNA content (defined as previously determined LOD). Mutation positive DNA samples were tested with the Control Reaction mix and relevant Mutation Reaction mixes. NSCLC samples diluted to the LOD mutation content level had an upper one-sided exact 95% confidence limit for the observed mutation positive detection rate greater than or equal to 95%, reverifying the CRC sample LOD values presented in .

### Cell line correlation study

The objective of this study was to determine the utility of FFPE NSCLC cell line samples as a suitable substitute for clinical FFPE NSCLC samples by comparing hit rates at, below, and above the established Limit of Detection (LOD) for DNA extracted from FFPE cell line samples and DNA extracted from clinical FFPE NSCLC tissue samples. Furthermore, the study was

performed to demonstrate that the FFPE cell line samples do not outperform clinical FFPE NSCLC samples when tested using the KRAS Kit.

The study used two *KRAS* mutation positive FFPE cell line samples (positive as detected by the *KRAS* Kit) and two *KRAS* clinical FFPE samples of the same mutation status. Six dilution levels that were expected to give C100 (1.5xLOD), C95 (LOD), C75, C50, C25 and C5 percent correct mutation calls were tested for each sample panel member. Two of the most prevalent *KRAS* codon 12 mutations G12C (12CYS) and G12D (12ASP) were used for this study.

Two Probit models were used for analysis. For the *KRAS* G12D mutation, the data outputs were not statistically significant indicating that there is no difference in performance between the cell line and clinical samples. However, for the *KRAS* G12C mutation, the positivity rate of the cell line was lower than that of the clinical samples at the different dilution levels, demonstrating that the cell line does not outperform the clinical sample. The study acceptance criteria were met whereby the 12ASP and 12CYS cell lines did not outperform the corresponding clinical samples and this the cell lines were used as substitutes where clinical samples were not available for validation studies.

## Comparison to analytical reference method

The purpose of this study was to demonstrate the concordance in overall mutation status of the *therascreen* KRAS RGQ PCR Kit NSCLC relative to bi-directional Sanger sequencing (Table 34).

**Table 34. Correlation between Sanger and KRAS RGQ result**

Sanger status	KRAS status		
	Mutation positive	No mutation detected	Total
Frequency (percent)			
Mutation positive	79 (21.94)	1 (0.28)	80 (22.22)

Table 34. Correlation between Sanger and KRAS RGQ result (continued)

Sanger status	KRAS status		
Frequency (percent)	Mutation positive	No mutation detected	Total
No mutation detected	21 (5.83)	259 (71.94)	280 (77.78)
Total	100 (27.78)	260 (72.22)	360 (100.00)

A set of 360 procured clinical NSCLC FFPE samples representing a mix of samples acquired by resection, FNA and CNB were used to evaluate the concordance between the KRAS Kit and Sanger bi-directional sequencing. DNA was extracted from each sample and tested with the KRAS Kit and bi-directional Sanger sequencing. Of the 360 valid samples, 340 samples produced concordant results between the KRAS Kit and bi-directional sequencing. Two of these concordant samples had one mutation call for the KRAS Kit but a double mutation for the bi-directional Sanger sequencing (one of which was the same as the one call by the KRAS Kit; therefore, a concordant result was given to these samples.

As seen in Table 35, the PPA was 98.75% (94.21, 99.94), the NPA was 93.21% (90.20, 95.51), and the OPA was 94.44% (92.03, 96.29).

Table 35. Agreement for Samples with both Sanger and KRAS Kit valid Results

Measure of agreement	Frequencies	Percentage agreement	Exact binomial lower two-sided 90% confidence limit	Exact binomial upper two-sided 90% confidence limit
Percentage Overall Agreement	340/360	94.44	92.03	96.29
Percentage Positive Agreement	79/80	98.75	94.21	99.94
Percentage Negative Agreement	261/280	93.21	90.20	95.51

There were 20 discordant samples; 19 were WT for the bi-directional Sanger sequencing but gave a mutation result for the KRAS Kit. One sample was WT for the KRAS Kit but gave a mutation positive (13ASP) status for the bi-directional Sanger sequencing.

## Equivalency of sample acquisition

The purpose of this study was to assess whether the mutation call for NSCLC samples determined by the *therascreen* KRAS RGQ PCR Kit was affected by the sample acquisition method. The 3 sample acquisition methods assessed in this study were resection, FNA, and CNB.

For this study, “patient-matched” CNB and FNA samples were derived from surgically resected (RES) tumor samples to enable the same tumor to be collected by the 3 acquisition methods. Each sample was extracted and tested with the *therascreen* KRAS RGQ PCR Kit.

The primary analysis was based on the specific mutation being detected across acquisition types. The measures of overall percentage agreement, positive percentage agreement, and negative percentage agreement were calculated along with the exact two-sided 95% confidence limit for each pair-wise comparison (Table 36).

**Table 36. Agreement between Sample Acquisitions Methods (Including samples valid with all 3 acquisition methods)**

Comparison	Agreement	Frequencies	Percentage (%)	Lower two-sided Confidence Limit (%)	Upper two-sided 95% Confidence Limits (%)
CNB Vs FNA with CNB as Reference	Overall Percent Agreement	148/156	94.87	90.15	97.76
	Positive Percent Agreement	29/35	82.86	66.35	93.44
	Negative Percent Agreement	119/121	98.35	94.16	99.80

**Table 36. Agreement between Sample Acquisitions Methods (Including samples valid with all 3 acquisition methods)**  
(continued)

Comparison	Agreement	Frequencies	Percentage (%)	Lower two-sided Confidence Limit (%)	Upper two-sided 95% Confidence Limits (%)
CNB Vs RES with CNB as Reference	Overall Percent Agreement	148/156	94.87	90.15	97.76
	Positive Percent Agreement	29/35	82.86	66.35	93.44
	Negative Percent Agreement	119/121	98.35	94.16	99.80
FNA Vs CNB with FNA as Reference	Overall Percent Agreement	148/156	94.87	90.15	97.76
	Positive Percent Agreement	29/32	90.63	74.98	98.02
	Negative Percent Agreement	119/124	95.97	90.84	98.68
FNA Vs RES with FNA as Reference	Overall Percent Agreement	152/156	97.44	93.57	99.30
	Positive Percent Agreement	30/32	93.75	79.19	99.23
	Negative Percent Agreement	122/124	98.39	94.30	99.80
RES Vs. CNB with RES as Reference	Overall Percent Agreement	148/156	94.87	90.15	97.76
	Positive Percent Agreement	29/32	90.63	74.98	98.02
	Negative Percent Agreement	119/124	95.97	90.84	98.68

Table 36. Agreement between Sample Acquisitions Methods (Including samples valid with all 3 acquisition methods)  
(continued)

Comparison	Agreement	Frequencies	Percentage (%)	Lower two-sided Confidence Limit (%)	Upper two-sided 95% Confidence Limits (%)
RES Vs. FNA with RES as Reference	Overall Percent Agreement	152/156	97.44	93.57	99.30
	Positive Percent Agreement	30/32	93.75	79.19	99.23
	Negative Percent Agreement	122/124	98.39	94.30	99.80

In addition, Passing-Bablok and Deming regression analysis was performed to compare Ct and  $\Delta$ Ct values between different sample acquisition methods. The regression analysis demonstrated that there is no evidence to suggest that there exists any constant or proportional difference between the RES, CNB, and FNA sample types in terms of Ct or  $\Delta$ Ct. A linear regression analysis was also performed to investigate the effect of both percentage of necrotic and tumor tissue on the relevant  $\Delta$ Ct values. The slope of the regression line for both necrotic and percent tumor vs  $\Delta$ Ct indicates that there is no evidence to suggest that there is any meaningful difference in  $\Delta$ Ct values with increasing values of the percentage or necrotic or tumor tissue.

## Repeatability and reproducibility

The precision of the *therascreen* KRAS RGQ PCR Kit within-laboratory (repeatability) was assessed. Both the correctness of mutation results and the precision of  $\Delta$ C<sub>T</sub> values (the difference in C<sub>T</sub> values between a Mutation Reaction and the Control Reaction) are reported.

In total, 15 panel members were prepared; one for each of the 7 mutations detected by the *therascreen* KRAS RGQ PCR Kit (at LOD and 2xLoD), and a wild type (WT) panel member. Mutant panel members were represented by either an FFPE cell line or a clinical sample depending on availability. All samples were normalized to a control Ct of 27 and mutant

samples were diluted in wild type DNA to generate sufficient material for samples at mutation levels of 1xLoD and 2xLoD.

The proportion of correct calls is presented in Table 37 for each test panel and the variance component values are presented in Table 38.

Table 37. Proportion of correct mutation calls

Grouping variables		Proportion		Two-sided 95% confidence limit	
Sample level	Assay	Fraction	Percentage (%)	Lower (%)	Upper (%)
2xLoD	12ALA	28/28	100.00	87.66	100.00
	12ARG*	28/28	100.00	87.66	100.00
	12ASP	28/28	100.00	87.66	100.00
	12CYS	28/28	100.00	87.66	100.00
	12SER*	28/28	100.00	87.66	100.00
	12VAL	28/28	100.00	87.66	100.00
	13ASP*	28/28	100.00	87.66	100.00
LoD	12ALA	39/40	97.50	86.84	99.94
	12ARG	40/40	100.00	91.19	100.00
	12ASP	40/40	100.00	91.19	100.00
	12CYS	40/40	100.00	91.19	100.00
	12SER*	40/40	100.00	91.19	100.00
	12VAL	40/40	100.00	91.19	100.00
	13ASP*	38/40	95.00	83.08	99.39
WT	All	28/28	100.00	87.66	100.00

\* Represented by FFPE cell line

Table 38. Variance components in terms of SD and %CV – repeatability

Analysis variable	Sample level	Assay	# of observations	Mean	Bet. Day*	Bet. Run N*	Bet. Rgq*	Bet. Kit lot*	Bet. Operator*	Residual*	Total
$\Delta C_T$	2xLoD	12ALA	28	5.54	(0.0000, 0.00%)	(0.1221, 2.20%)	(0.0443, 0.80%)	(0.0385, 0.70%)	(0.0000, 0.00%)	(0.1335, 2.41%)	(0.1843, 3.33%)
		12ARG	28	4.80	(0.0000, 0.00%)	(0.1891, 3.94%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.3244, 6.76%)	(0.3737, 7.79%)
		12ASP	28	4.72	(0.0860, 1.82%)	(0.1446, 3.06%)	(0.0000, 0.00%)	(0.1463, 3.10%)	(0.1374, 2.91%)	(0.1751, 3.71%)	(0.2797, 5.93%)
		12CYS	28	5.66	(0.0563, 0.99%)	(0.0000, 0.00%)	(0.0995, 1.76%)	(0.0000, 0.00%)	(0.0390, 0.69%)	(0.2306, 4.08%)	(0.2498, 4.41%)
		12SER	28	5.36	(0.1429, 2.67%)	(0.0274, 0.51%)	(0.0000, 0.00%)	(0.0647, 1.21%)	(0.0000, 0.00%)	(0.1753, 3.27%)	(0.2129, 3.97%)
		12VAL	28	4.26	(0.0000, 0.00%)	(0.1016, 2.39%)	(0.0593, 1.39%)	(0.1128, 2.65%)	(0.0000, 0.00%)	(0.2095, 4.92%)	(0.2457, 5.77%)
		13ASP	28	5.23	(0.0000, 0.00%)	(0.2892, 5.53%)	(0.0157, 0.30%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2171, 4.15%)	(0.3575, 6.83%)
	LoD	12ALA	40	6.36	(0.0000, 0.00%)	(0.1584, 2.49%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2346, 3.69%)	(0.2819, 4.43%)
		12ARG	40	5.45	(0.0036, 0.07%)	(0.1639, 3.01%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0797, 1.46%)	(0.1674, 3.07%)	(0.2397, 4.40%)
		12ASP	40	4.73	(0.0000, 0.00%)	(0.2485, 5.25%)	(0.1087, 2.30%)	(0.0000, 0.00%)	(0.0816, 1.72%)	(0.1041, 2.20%)	(0.2837, 6.00%)
		12CYS	40	6.62	(0.1688, 2.55%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2056, 3.11%)	(0.0000, 0.00%)	(0.2909, 4.40%)	(0.3652, 5.52%)
		12SER	40	6.37	(0.1006, 1.58%)	(0.3153, 4.95%)	(0.0000, 0.00%)	(0.0340, 0.53%)	(0.0000, 0.00%)	(0.2253, 3.54%)	(0.3854, 6.05%)

Table 38. Variance components in terms of SD and %CV – repeatability (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Bet. Day*	Bet. Run N*	Bet. Rgq*	Bet. Kit lot*	Bet. Operator*	Residual*	Total
GreenCT	2xLoD	12VAL	40	5.13	(0.2874, 5.60%)	(0.0976, 1.90%)	(0.0227, 0.44%)	(0.0874, 1.71%)	(0.0000, 0.00%)	(0.1629, 3.18%)	(0.2965, 5.78%)
		13ASP	38	6.26	(0.3433, 5.48%)	(0.1227, 1.96%)	(0.0778, 1.24%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.3459, 5.52%)	(0.4738, 7.57%)
		12ALA	28	32.09	(0.0000, 0.00%)	(0.1314, 0.41%)	(0.0000, 0.00%)	(0.0675, 0.21%)	(0.1073, 0.33%)	(0.1158, 0.36%)	(0.1957, 0.61%)
		12ARG	28	31.50	(0.0000, 0.00%)	(0.2598, 0.82%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.3324, 1.06%)	(0.4189, 1.33%)
		12ASP	28	31.30	(0.0000, 0.00%)	(0.1891, 0.60%)	(0.0000, 0.00%)	(0.0920, 0.29%)	(0.0000, 0.00%)	(0.1800, 0.58%)	(0.2667, 0.85%)
		12CYS	28	32.07	(0.0000, 0.00%)	(0.2523, 0.79%)	(0.0000, 0.00%)	(0.1606, 0.50%)	(0.2011, 0.63%)	(0.1512, 0.47%)	(0.3388, 1.06%)
	LoD	12SER	28	32.06	(0.0000, 0.00%)	(0.2049, 0.64%)	(0.0000, 0.00%)	(0.1250, 0.39%)	(0.1177, 0.37%)	(0.1263, 0.39%)	(0.2648, 0.83%)
		12VAL	28	30.65	(0.0000, 0.00%)	(0.1772, 0.58%)	(0.0000, 0.00%)	(0.1198, 0.39%)	(0.1063, 0.35%)	(0.1656, 0.54%)	(0.2639, 0.86%)
		13ASP	28	31.98	(0.0000, 0.00%)	(0.3773, 1.18%)	(0.0497, 0.16%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1813, 0.57%)	(0.4138, 1.29%)
		12ALA	40	32.86	(0.0000, 0.00%)	(0.2332, 0.71%)	(0.0516, 0.16%)	(0.0840, 0.26%)	(0.1319, 0.40%)	(0.1780, 0.54%)	(0.3144, 0.96%)
GreenCT	2xLoD	12ARG	40	31.90	(0.0000, 0.00%)	(0.2186, 0.69%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2289, 0.72%)	(0.1519, 0.48%)	(0.3106, 0.97%)
		12ASP	40	31.02	(0.0000, 0.00%)	(0.1762, 0.57%)	(0.1093, 0.35%)	(0.1296, 0.42%)	(0.2492, 0.80%)	(0.1005, 0.32%)	(0.2908, 0.94%)

Table 38. Variance components in terms of SD and %CV – repeatability (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Bet. Day*	Bet. Run N*	Bet. Rgq*	Bet. Kit lot*	Bet. Operator*	Residual*	Total
YellowCT	2xLoD	12CYS	40	33.14	(0.1216, 0.37%)	(0.0493, 0.15%)	(0.0000, 0.00%)	(0.3468, 1.05%)	(0.0501, 0.15%)	(0.3155, 0.95%)	(0.4216, 1.27%)
		12SER	40	33.08	(0.0832, 25%)	(0.2591, 0.78%)	(0.0000, 0.00%)	(0.2424, 0.73%)	(0.0000, 0.00%)	(0.2258, 0.68%)	(0.3864, 1.17%)
		12VAL	40	31.62	(0.2858, 0.90%)	(0.0951, 0.30%)	(0.0000, 0.00%)	(0.2244, 0.71%)	(0.0344, 0.11%)	(0.1763, 0.56%)	(0.3432, 1.09%)
		13ASP	38	33.09	(0.3237, 0.98%)	(0.1009, 0.31%)	(0.1409, 0.43%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2785, 0.84%)	0.4133,
	LoD	12ALA	28	33.20	(0.0000, 0.00%)	(0.0515, 0.16%)	(0.0330, 0.10%)	(0.0000, 0.00%)	(0.0607, 0.18%)	(0.2117, 0.64%)	(0.2235, 0.67%)
		12ARG	28	33.05	(0.1397, 0.42%)	(0.1321, 0.40%)	(0.0000, 0.00%)	(0.2393, 0.72%)	(0.0000, 0.00%)	(0.3792, 1.15%)	(0.4559, 1.38%)
		12ASP	28	33.00	(0.0597, 0.18%)	(0.2131, 0.65%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1313, 0.40%)	(0.1954, 0.59%)	(0.3059, 0.93%)
		12CYS	28	33.19	(0.0646, 0.19%)	(0.0971, 0.29%)	(0.0233, 0.07%)	(0.0679, 0.20%)	(0.0863, 0.26%)	(0.1943, 0.59%)	(0.2378, 0.72%)
		12SER	28	32.85	(0.0525, 0.16%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0337, 0.10%)	(0.0937, 0.29%)	(0.1320, 0.40%)	(0.1588, 0.48%)
LoD	LoD	12VAL	28	33.11	(0.0000, 0.00%)	(0.1026, 0.31%)	(0.0000, 0.00%)	(0.1469, 0.44%)	(0.1469, 0.44%)	(0.2912, 0.88%)	(0.3458, 1.04%)
		13ASP	28	33.03	(0.0000, 0.00%)	(0.1928, 0.58%)	(0.1015, 0.31%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1450, 0.44%)	(0.2493, 0.75%)
LoD	LoD	12ALA	40	33.37	(0.0000, 0.00%)	(0.2010, 0.60%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1942, 0.58%)	(0.2177, 0.65%)	(0.3257, 0.98%)

Table 38. Variance components in terms of SD and %CV – repeatability (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Bet. Day*	Bet. Run N*	Bet. Rgq*	Bet. Kit lot*	Bet. Operator*	Residual*	Total
YellowCT	WT	12ARG	40	33.14	(0.0000, 0.00%)	(0.2168, 0.65%)	(0.0000, 0.00%)	(0.3061, 0.92%)	(0.1637, 0.49%)	(0.1748, 0.53%)	(0.3717, 1.120%)
		12ASP	40	32.98	(0.0000, 0.00%)	(0.2599, 0.79%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1735, 0.53%)	(0.2228, 0.68%)	(0.3618, 1.10%)
		12CYS	40	33.31	(0.0000, 0.00%)	(0.2028, 0.61%)	(0.0000, 0.00%)	(0.1209, 0.36%)	(0.0000, 0.00%)	(0.2132, 0.64%)	(0.3050, 0.92%)
		12SER	40	33.08	(0.1254, 0.38%)	(0.2847, 0.86%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1505, 0.46%)	(0.3263, 0.99%)
		12VAL	40	33.29	(0.3133, 0.94%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2621, 0.79%)	(0.3574, 1.07%)
		13ASP	40	33.13	(0.1101, 0.33%)	(0.1326, 0.40%)	(0.1666, 0.50%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1925, 0.58%)	(0.2804, 0.85%)
		12ALA	28	33.41	(0.1443, 0.43%)	(0.1997, 0.60%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2269, 0.68%)	(0.3248, 0.97%)
		12ARG	28	33.30	(0.0875, 0.26%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.4098, 1.23%)	(0.0904, 0.27%)	(0.2368, 0.71%)	(0.3983, 1.20%)
		12ASP	28	33.12	(0.1591, 0.48%)	(0.1748, 0.53%)	(0.0477, 0.14%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.2131, 0.64%)	(0.3075, 0.93%)
		12CYS	28	33.42	(0.0000, 0.00%)	(0.2009, 0.60%)	(0.0000, 0.00%)	(0.1444, 0.43%)	(0.0000, 0.00%)	(0.2121, 0.63%)	(0.3077, 0.92%)
		12SER	28	33.22	(0.2485, 0.75%)	(0.0000, 0.00%)	(0.0633, 0.19%)	(0.0000, 0.00%)	(0.0000, 0.00%)	(0.1497, 0.45%)	(0.2517, 0.76%)
		12VAL	28	33.35	(0.0000, 0.00%)	(0.2591, 0.78%)	(0.0000, 0.00%)	(0.1429, 0.43%)	(0.0000, 0.00%)	(0.2721, 0.82%)	(0.3863, 1.16%)

Table 38. Variance components in terms of SD and %CV – repeatability (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Bet. Day*	Bet. Run N*	Bet. Rgq*	Bet. Kit lot*	Bet. Operator*	Residual*	Total
		13ASP	28	33.45	(0.0000, 0.00%)	(0.1194, 0.36%)	(0.0526, 0.16%)	(0.0341, 0.10%)	(0.0000, 0.00%)	(0.1651, 0.49%)	(0.2078, 0.62%)

\* SD, %CV

The precision of the *therascreen* KRAS RGQ PCR Kit between-laboratories (reproducibility) was assessed. Three different laboratories (test sites) were used. The same test panel was used for this study as for the repeatability study. At each site, laboratory conditions were varied by RGQ instrument, operator, *therascreen* KRAS RGQ PCR Kit lot, and runs per day to yield a total of 88 runs per site over 22 non-consecutive days.

The proportion of correct mutation calls is reported in Table 39. The quantitative precision values are presented in Table 40. The total reproducibility of the *therascreen* KRAS RGQ PCR Kit is shown in the #Total (SD, CV%) column of Table 40.

Table 39. Proportion of correct mutation calls across all sites

Grouping variables		Proportion		Two-sided 95% confidence limit	
Sample level	Assay	Fraction	Percentage (%)	Lower (%)	Upper (%)
2xLoD	12ALA	84/84	100.00	95.70	100.00
	12ARG*	84/84	100.00	95.70	100.00
	12ASP	84/84	100.00	95.70	100.00
	12CYS	84/84	100.00	95.70	100.00
	12SER*	84/84	100.00	95.70	100.00
	12VAL	84/84	100.00	95.70	100.00
	13ASP*	84/84	100.00	95.70	100.00
LoD	12ALA	118/120	98.33	94.11	99.80
	12ARG	120/120	100.00	96.97	100.00
	12ASP	120/120	100.00	96.97	100.00
	12CYS	119/120	99.17	95.44	99.88
	12SER*	120/120	100.00	96.97	100.00
	12VAL	120/120	100.00	96.97	100.00
	13ASP*	118/120	98.33	94.11	99.80
WT	All	82/84	97.62	91.66	99.71

\* Represented by FFPE cell line.

Table 40. Variance components in terms of SD and %CV – reproducibility

Analysis variable	Sample level	Assay	# of observations	Mean	Between site* within site*	Between day within site*	Between run within site*	Between Rgt within site*	Between within site*	Residual*	Total
$\Delta C_T$	2xLoD	12ALA	84	5.48	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1669, 3.05%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1287, 2.35%]	[0.1679, 3.07%]
		12ARG	84	4.81	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1172, 2.43%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2967, 6.16%]
		12ASP	84	4.57	[0.0000, 0.00%]	[0.0943, 2.06%]	[0.1457, 3.19%]	[0.0000, 0.00%]	[0.0600, 1.31%]	[0.1718, 3.76%]	[0.2854, 6.25%]
		12CVS	84	5.61	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2060, 3.67%]	[0.0264, 0.47%]	[0.0698, 1.24%]	[0.0000, 0.00%]	[0.2728, 4.87%]
		12SER	84	5.34	[0.0000, 0.00%]	[0.1362, 2.55%]	[0.1669, 3.13%]	[0.1527, 2.86%]	[0.0000, 0.00%]	[0.2020, 3.79%]	[0.3902, 7.31%]
		12VAL	84	4.13	[0.0874, 2.11%]	[0.0000, 0.00%]	[0.1677, 4.06%]	[0.0000, 0.00%]	[0.0869, 2.10%]	[0.0000, 0.00%]	[0.3359, 8.12%]
	13ASP	13ASP	84	5.22	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2161, 4.14%]	[0.2712, 5.20%]	[0.0000, 0.00%]	[0.1930, 3.70%]	[0.4279, 8.20%]
		12ALA	119	6.33	[0.0000, 0.00%]	[0.0410, 0.65%]	[0.1207, 1.91%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.0247, 0.39%]	[0.2936, 4.64%]
		12ARG	120	5.42	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1797, 3.31%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2590, 4.78%]
		12ASP	120	4.66	[0.1183, 2.54%]	[0.0646, 1.38%]	[0.2121, 4.55%]	[0.0261, 0.56%]	[0.0217, 0.46%]	[0.0440, 0.94%]	[0.2862, 6.14%]
		12CVS	120	6.54	[0.0000, 0.00%]	[0.0132, 0.20%]	[0.1775, 2.72%]	[0.0000, 0.00%]	[0.1621, 2.48%]	[0.1708, 2.61%]	[0.4981, 7.62%]
		12SER	120	6.28	[0.0000, 0.00%]	[0.0824, 1.31%]	[0.2271, 3.62%]	[0.0775, 1.24%]	[0.0000, 0.00%]	[0.2383, 3.80%]	[0.4570, 7.28%]

Table 40. Variance components in terms of SD and %CV – reproducibility (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Between-site* within-site*	Between-day within-site*	BetweenRun within-site*	BetweenRq within-site*	BetweenRun within-site*	Residual*	Total
Green C <sub>T</sub>		12VAL	120	5.05	[0.0315, 0.62%]	[0.1648, 3.26%]	[0.0955, 1.89%]	[0.0703, 1.39%]	[0.0320, 0.63%]	[0.0795, 1.57%]	[0.2120, 4.20%] [0.2965, 5.87%]
		13ASP	118	6.17	[0.0000, 0.00%]	[0.1673, 2.71%]	[0.1987, 3.22%]	[0.2332, 3.78%]	[0.0000, 0.00%]	[0.0843, 1.37%]	[0.3075, 4.99%] [0.4488, 7.28%]
		12ALA	84	32.13	[0.1578, 0.49%]	[0.0000, 0.00%]	[0.2509, 0.78%]	[0.0745, 0.23%]	[0.0000, 0.00%]	[0.1249, 0.39%]	[0.1362, 0.42%] [0.3390, 1.06%]
		12ARG	84	31.61	[0.0882, 0.28%]	[0.0000, 0.00%]	[0.2430, 0.77%]	[0.1339, 0.42%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2604, 0.82%] [0.3828, 1.21%]
		12ASP	84	31.24	[0.1655, 0.53%]	[0.0391, 0.13%]	[0.2178, 0.70%]	[0.0600, 0.19%]	[0.0000, 0.00%]	[0.2052, 0.66%]	[0.1426, 0.46%] [0.3542, 1.13%]
		12CYS	84	32.15	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2836, 0.88%]	[0.0852, 0.26%]	[0.0940, 0.29%]	[0.1658, 0.52%]	[0.1318, 0.41%] [0.3636, 1.13%]
	LoD	12SER	84	32.14	[0.1457, 0.45%]	[0.0000, 0.00%]	[0.2659, 0.83%]	[0.1807, 0.56%]	[0.0000, 0.00%]	[0.2715, 0.84%]	[0.1783, 0.55%] [0.4554, 1.42%]
		12VAL	84	30.69	[0.0646, 0.21%]	[0.0480, 0.16%]	[0.2124, 0.69%]	[0.0000, 0.00%]	[0.1031, 0.34%]	[0.0000, 0.00%]	[0.3143, 1.02%] [0.4518, 1.31%]
		13ASP	84	32.12	[0.2111, 0.66%]	[0.0000, 0.00%]	[0.3218, 1.00%]	[0.2966, 0.92%]	[0.0000, 0.00%]	[0.1743, 0.54%]	[0.5184, 1.61%] [0.7211, 2.13%]
		12ALA	119	32.93	[0.0000, 0.00%]	[0.1524, 0.46%]	[0.1821, 0.55%]	[0.1048, 0.32%]	[0.0757, 0.23%]	[0.1007, 0.31%]	[0.2526, 0.77%] [0.3721, 1.13%]
		12ARG	120	31.98	[0.0000, 0.00%]	[0.0743, 0.23%]	[0.1936, 0.61%]	[0.1262, 0.39%]	[0.0000, 0.00%]	[0.1332, 0.42%]	[0.1619, 0.51%] [0.3096, 0.97%]
		12ASP	120	31.06	[0.1880, 0.61%]	[0.1184, 0.38%]	[0.1681, 0.54%]	[0.1033, 0.33%]	[0.1171, 0.38%]	[0.1481, 0.48%]	[0.1333, 0.43%] [0.3511, 1.13%]

Table 40. Variance components in terms of SD and %CV – reproducibility (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Between-site <sup>a</sup>	Between-day within-site <sup>a</sup>	Between-run within-site <sup>a</sup>	Between-plate within-site <sup>a</sup>	Between-plate within-site <sup>a</sup>	Residual <sup>a</sup>	Total	
Yellow C <sub>T</sub>		12CVS	120	33.19	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2513, 0.76%]	[0.0776, 0.23%]	[0.2128, 0.64%]	[0.1427, 0.43%]	[0.2712, 0.82%]	[0.4401, 1.33%]
		12SER	120	33.13	[0.2194, 0.66%]	[0.0000, 0.00%]	[0.2433, 0.73%]	[0.1263, 0.38%]	[0.1470, 0.44%]	[0.1973, 0.60%]	[0.2052, 0.62%]	[0.4437, 1.34%]
		12VAL	120	31.65	[0.0000, 0.00%]	[0.1254, 0.40%]	[0.1645, 0.52%]	[0.1307, 0.41%]	[0.1271, 0.40%]	[0.0976, 0.31%]	[0.1792, 0.57%]	[0.3159, 1.00%]
		13ASP	118	33.08	[0.0000, 0.00%]	[0.1789, 0.54%]	[0.1661, 0.50%]	[0.3569, 1.08%]	[0.0649, 0.20%]	[0.1565, 0.47%]	[0.2588, 0.78%]	[0.4894, 1.48%]
		12ALA	84	33.25	[0.0706, 0.21%]	[0.0399, 0.12%]	[0.1314, 0.40%]	[0.1303, 0.39%]	[0.0000, 0.00%]	[0.1124, 0.34%]	[0.1913, 0.58%]	[0.2883, 0.87%]
		12ARG	84	33.07	[0.0000, 0.00%]	[0.1406, 0.43%]	[0.1353, 0.41%]	[0.0000, 0.00%]	[0.2024, 0.61%]	[0.1262, 0.38%]	[0.2831, 0.86%]	[0.4016, 1.21%]
		12ASP	84	32.98	[0.0000, 0.00%]	[0.0480, 0.15%]	[0.1706, 0.52%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.0797, 0.24%]	[0.1795, 0.54%]	[0.2616, 0.79%]
		12CVS	84	33.20	[0.0000, 0.00%]	[0.0976, 0.29%]	[0.1781, 0.54%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1454, 0.44%]	[0.1723, 0.52%]	[0.2939, 0.89%]
		12SER	84	32.91	[0.0000, 0.00%]	[0.1101, 0.33%]	[0.0549, 0.17%]	[0.0669, 0.20%]	[0.0677, 0.21%]	[0.1186, 0.36%]	[0.2274, 0.69%]	[0.2916, 0.89%]
		12VAL	84	33.17	[0.0688, 0.21%]	[0.0000, 0.00%]	[0.1896, 0.57%]	[0.0937, 0.28%]	[0.1140, 0.34%]	[0.1311, 0.40%]	[0.2605, 0.79%]	[0.3768, 1.14%]
		13ASP	84	33.10	[0.0000, 0.00%]	[0.0482, 0.15%]	[0.2035, 0.61%]	[0.0000, 0.00%]	[0.0466, 0.14%]	[0.1460, 0.44%]	[0.1688, 0.51%]	[0.3019, 0.91%]
		12ALA	119	33.33	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2108, 0.63%]	[0.0820, 0.25%]	[0.0000, 0.00%]	[0.1443, 0.43%]	[0.2253, 0.68%]	[0.3411, 1.02%]

Table 40. Variance components in terms of SD and %CV – reproducibility (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Between site* within site*	Between day within site*	Between Run within site*	Between Rep within site*	Between well within site*	Residual*	Total
WT		12ARG	120	33.15	[0.1092, 0.33%]	[0.0537, 0.16%]	[0.1605, 0.48%]	[0.0507, 0.15%]	[0.2157, 0.65%]	[0.1276, 0.39%]	[0.2180, 0.66%]
		12ASP	120	32.96	[0.0000, 0.00%]	[0.0832, 0.25%]	[0.2022, 0.61%]	[0.0864, 0.26%]	[0.0000, 0.00%]	[0.1117, 0.34%]	[0.3343, 1.01%]
		12CVS	120	33.26	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2232, 0.67%]	[0.1691, 0.51%]	[0.0789, 0.24%]	[0.0000, 0.00%]	[0.3516, 1.06%]
		12SER	120	33.01	[0.1573, 0.48%]	[0.0716, 0.22%]	[0.2134, 0.65%]	[0.0951, 0.29%]	[0.0000, 0.00%]	[0.0784, 0.24%]	[0.3263, 0.99%]
		12VAL	120	33.25	[0.1519, 0.46%]	[0.1960, 0.59%]	[0.1272, 0.38%]	[0.0000, 0.00%]	[0.1298, 0.39%]	[0.0553, 0.17%]	[0.3487, 1.05%]
		13ASP	118	33.16	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1768, 0.53%]	[0.0998, 0.30%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2802, 0.84%]
		12ALA	84	33.44	[0.1257, 0.38%]	[0.0961, 0.29%]	[0.1845, 0.55%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.3104, 0.93%]
		12ARG	84	33.37	[0.1191, 0.36%]	[0.0000, 0.00%]	[0.1869, 0.56%]	[0.1321, 0.40%]	[0.2529, 0.76%]	[0.1205, 0.36%]	[0.4217, 1.26%]
		12ASP	84	33.16	[0.0574, 0.17%]	[0.0738, 0.22%]	[0.2162, 0.65%]	[0.0563, 0.17%]	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.2997, 0.90%]
		12CVS	84	33.42	[0.0000, 0.00%]	[0.0000, 0.00%]	[0.1964, 0.59%]	[0.0720, 0.22%]	[0.1311, 0.39%]	[0.0262, 0.08%]	[0.3287, 0.98%]
		12SER	84	33.20	[0.0812, 0.24%]	[0.1331, 0.40%]	[0.1734, 0.52%]	[0.0329, 0.10%]	[0.0000, 0.00%]	[0.2009, 0.61%]	[0.3535, 1.06%]
		12VAL	84	33.41	[0.0000, 0.00%]	[0.0695, 0.21%]	[0.2046, 0.61%]	[0.0000, 0.00%]	[0.1708, 0.51%]	[0.1437, 0.43%]	[0.3799, 1.14%]

Table 40. Variance components in terms of SD and %CV – reproducibility (continued)

Analysis variable	Sample level	Assay	# of observations	Mean	Between site* within site*	Between Run within site*	Between Rq within site*	Between site*	Residual* within site*	Total
	13ASP	84	33.46	(0.0000, 0.00%)	(0.0613, 0.18%)	(0.1802, 0.54%)	(0.0744, 0.22%)	(0.0073, 0.02%)	(0.1790, 0.53%)	(0.2816, 0.84%)

\* SD, %CV

## Analytical accuracy (using clinical samples)

A study demonstrating the concordance in mutation detection of the *therascreen* KRAS RGQ PCR Kit relative to a validated Droplet Digital PCR (ddPCR) method was performed. A total of 319 samples with both ddPCR and *therascreen* KRAS RGQ PCR Kit results were analyzed to assess the positive percent agreement (PPA), negative percent agreement (NPA), and overall percent agreement (OPA).

The 319 samples used in the analysis were a combination of clinical samples from Amgen Clinical Study 20170543 and procured NSCLC samples. For both methods, samples returning a result other than G12C were considered as mutation negative for this analysis. Of the 319 samples, 5 were invalid by ddPCR.

The OPA, NPA, and PPA, together with the corresponding two-sided 95% confidence intervals (CI), are summarized in Table 41. The OPA was 97.45%. A breakdown of the results is summarized in Table 42.

**Table 41. OPA, PPA, and NPA of KRAS kit vs. ddPCR (two-sided 95% confidence interval)**

Grouping variables	Proportion		Two-sided 95% confidence limit	
Group	Fraction	Percentage	Lower	Upper
Overall Percentage agreement (OPA)	306 / 314	97.45%	95.04%	98.89%
Positive percent agreement (PPA)	149 / 150	99.33%	96.34%	99.98%
Negative percent agreement (NPA)	157 / 164	95.73%	91.40%	98.27%

Table 42. 2x2 Frequency table KRAS kit vs. ddPCR

<i>therascreen</i> KRAS G12C result		ddPCR G12C result		
Frequency	G12C	G12C Not Detected	Invalid	Total
G12C	149	7	4	160
G12C Not Detected	1	157	1	159
Total	150	164	5	319

Non-specific amplification

The objective of this study was to assess the level of background amplification in wild type samples that have the highest concentration of input DNA within the KRAS kit working range. At high DNA input levels, the  $\Delta C_t$  values observed from non-specific amplification in all 60 replicates of the clinical wild-type were above the reaction mix cut-off values. The *therascreen* KRAS RGQ PCR Kit. correctly identified all 60 wild-type replicates as No Mutation Detected (wild-type).

Effect of input DNA

The DNA input level is the total quantity of amplifiable *KRAS* DNA (both mutant and wild type) in a sample. This is determined by the  $C_T$  value from the Control Reaction. When samples at different total DNA levels contain the same proportion of mutant DNA, it is expected that the measured  $\Delta C_T$  values (i.e. the difference in  $C_T$  values between a Mutation Reaction and the Control Reaction) will remain consistent and therefore, that the sample mutation result will not be dependent upon, or influenced by, the DNA input level. This study included 2 parts.

Part 1 was designed to address the effect of input DNA levels on  $\Delta C_T$  values. DNA extracted from nine FFPE NSCLC samples (4 Cell Lines and 5 Clinical) were used in this study. Samples were diluted to a Control Reaction  $C_T$  value of approximately 20.00-21.00  $C_T$  and from this,

a pool of DNA for each mutation sufficient for 6 replicates was serially diluted 10-fold over 4 points to correspond to a  $C_T$  value of approximately 32.00–33.00  $C_T$  (Table 43).

**Table 43. Dilution series for study on input DNA levels on  $\Delta C_T$  values**

Dilution factor	Initial pool	x10 (Dilution 1)	x100 (Dilution 2)	x1000 (Dilution 3)	x10000 (Dilution 4)
Expected Control $C_T$ values	Approx. 20.00–21.00 $C_T$	Approx. 23.00–24.00 $C_T$	Approx. 26.00–27.00 $C_T$	Approx. 29.00–30.00 $C_T$	Approx. 32.00–33.00 $C_T$

This range was designed to span the DNA input range for samples (Control Reaction  $C_T$  of 21.92– 32.00  $C_T$ ), including one dilution point at a higher than acceptable DNA concentration and one dilution point at a lower than acceptable DNA concentration. All 5 DNA input levels for each mutation were tested using the Control reaction mix and corresponding Mutation reaction mix on a single PCR run.

Linear regression plots were generated to show the  $\Delta C_T$  values for each mutation type across the dilutions within the Control  $C_T$  working range. The study acceptance criteria for part 1 of the study was met for all mutations as the linear regression lines and corresponding two-sided 95% confidence limits for the 3 dilutions within the Control  $C_T$  working range fell within the mean  $\pm$  1.96x Standard Deviation for Reproducibility as calculated in a repeatability and reproducibility study. The  $\Delta C_T$  values are consistent across the working range of the *therascreen* KRAS RGQ PCR Kit for all assays, demonstrating that the DNA input level will not impact the mutation calling for samples.

Part 2 of the study was designed to evaluate the effect of serially diluting a mutant positive sample on amplification efficiency by testing samples with varying percentage mutation at a high DNA input level (Control Reaction of approximately 23.00  $C_T$ ). DNA from clinical FFPE NSCLC and FFPE Cell Line sample pools was diluted to optical densities corresponding to Control Reaction  $C_T$  values of approximately 22.00-23.00  $C_T$ . Mutant DNA was serially diluted 2-fold into normalized wild-type DNA to create a series of 5 dilutions per mutant DNA

sample that varied in their mutation percentage (targeting 100%, 50%, 25%, 12.5%, and 6.25% percentage mutant).

Table 44 summarizes all of the amplification efficiencies for each assay. Amplification efficiencies of wild-type DNA relative to mutant DNA present in a sample did not impact  $\Delta C_T$  values and thus mutation call was not affected.

**Table 44. Amplification efficiencies of the mutation assay**

Sample	Amplification efficiency
12ALA	0.921
12ASP	1.034
12ARG	1.039
12CYS	0.988
12SER	1.047
12VAL	1.082
13ASP	1.085

**Non-specific amplification/cross-reactivity/exclusivity: mutation-positive KRAS DNA**

Mutant samples that have a high concentration of input DNA were tested against all reaction mixes by preparing DNA samples from each of the FFPE cell lines so that the control reaction  $C_T$  corresponded to approximately 23. Six replicates of each mutation sample were evaluated. The percentage of mutation in the sample was governed by the percentage of mutant in the cell line DNA. The mean  $\Delta C_T$  values are presented in Table 45 and demonstrate that there is cross-reactivity between mutant reactions. The 12ALA mutation was amplified and generated  $\Delta C_T$  values below the  $\Delta C_T$  thresholds for the 12CYS, 12SER, and 12VAL reactions. The 12VAL mutation was amplified and generated a  $\Delta C_T$  value below the  $\Delta C_T$  threshold for

the 12ALA reaction. The 12CYS mutation was amplified and generated a  $\Delta C_T$  value below the  $\Delta C_T$  threshold for the 12ARG reaction. In all cases, the results demonstrate that the correct mutation was called with the matched mutation reaction (i.e., the smallest  $\Delta C_T$  value was the correct mutation call). All other test cases were either not detected or outside the  $\Delta C_T$  threshold.

Table 45. Cross Reactivity NSCLC

Assay								
Sample	Cut-off	12ALA	12ASP	12ARG	12CYS	12SER	12VAL	13ASP
12ALA	8	1.31	12.80	–	5.01	2.26	5.57	12.65
12ASP	6.6	12.61	1.66	–	–	–	10.30	12.69
12ARG	8	12.98	11.08	0.81	11.24	–	12.66	12.62
12CYS	8	–	12.22	7.84	0.56	–	13.06	11.84
12SER	8	–	12.87	13.21	–	1.93	13.25	12.93
12VAL	7.5	5.93	14.29	–	–	13.14	0.45	12.39
13ASP	7.5	–	–	–	–	–	–	2.02

## Sample handling variability

A study was performed to demonstrate that different laboratories produced the same results when analyzing the same clinical samples. This study used a combination of FFPE Cell Line and Clinical FFPE NSCLC samples. Thirteen Clinical FFPE NSCLC samples were used; three for 12ASP, three for 12CYS, and four for 12VAL mutations (a total of 10 mutation samples) plus three wild-type samples. Four FFPE Cell Line samples positive for the mutations 12ALA, 12ARG, 12SER, and 13ASP were used. Samples were blinded so that the mutation status was unknown to the operators at each of the three test sites. At each of the three sites, DNA extraction was performed on a batch of 20 FFPE sections (i.e. 10 pairs) per Mutation and wild-type. A total of 314 extractions were carried out across the three sites. All sample

preparations at 3 individual test sites, when tested with the *therascreen* KRAS RGQ PCR Kit provided a correct mutation call for each of the seven mutations and the wild-type samples. The overall call for each of the seven mutations and the wild-type samples was 100% correct demonstrating inter-site consistency for the DNA extraction procedure and mutation detection using the KRAS Kit.

An additional Sample Handling study was conducted using clinical FFPE clinical NSCLC samples representative of 12ALA, 12ARG, 12SER, and 13ASP mutations, as the previous study used cell line samples representative of these mutations. This additional study followed the same study design as the previous study. All sample preparations for 12ALA, 12ARG, and 13ASP mutant samples extracted across all three individual test sites, provided a correct mutation call when tested with the KRAS Kit. The overall correct call for these samples was 100%. Sample preparations for 12SER mutation provided a frequency of correct mutation call of 28/30 (percentage of correct call equal to 93.33%) across all three individual test sites. The results demonstrate the consistency of the DNA extraction procedure and sample processing workflow used to perform testing with the *therascreen* KRAS RGQ PCR Kit.

## Lot interchangeability

The objective of this study was to establish that the use of different lots of the QIAamp DSP DNA FFPE Tissue Kit for extraction and *therascreen* KRAS RGQ PCR Kit for *KRAS* mutation analysis did not have an impact on the sample mutation status of a tested sample. Three lots of each kit were used to test FFPE NSCLC samples to establish that the use of different lots of the QIAamp DSP DNA FFPE Tissue Kit and the *therascreen* KRAS RGQ PCR Kit did not impact the sample mutation status of tested samples. Twenty-four (24) NSCLC samples, three each for the seven mutations detected by the *therascreen* KRAS RGQ PCR Kit plus three wild-type samples were used in the study. Each sample was extracted using three lots of the QIAamp DSP DNA FFPE Tissue Kit. All DNA extracts were tested with each of the three lots of *therascreen* KRAS RGQ PCR Kit within the same PCR run on the RGQ instrument.

The  $\Delta C_T$  values (the difference in  $C_T$  values between a Mutation Reaction and the Control Reaction) and mutation calls were collected for all test samples extracted with different QIAamp DSP DNA FFPE Tissue Kits and tested with different *therascreen* KRAS RGQ PCR Kits. The acceptance criterion of “at least 95% of mutations calls must be correct for the overall proportion” was met with each mutation and wild-type being called 100% correctly.

## Stability of FFPE sections

The main objective of this study was to demonstrate that sections prepared from resected FFPE NSCLC samples were stable when stored in the dark at ambient temperature. Sample sections from five *KRAS* mutation positive clinical FFPE NSCLC samples (one of each of the mutations 12ALA, 12ASP, 12CYS, 12VAL, and 13ASP) and one *KRAS* wild-type sample were sectioned and stored until required. The sections were tested with the *therascreen* KRAS RGQ PCR Kit over five time points spanning 75 weeks. All samples provided the correct mutation status call at all the time points. This study demonstrated that FFPE sections are stable at ambient temperature for at least 70 weeks.

A second study was performed to demonstrate that sections prepared from FFPE NSCLC FNA samples are stable when stored in the dark at ambient temperature.

This study used FNA samples that are wild type for the seven *KRAS* mutations that are detected by the *therascreen* KRAS RGQ PCR Kit. Sections from ten *KRAS* wild-type samples were used. These samples were extracted using one lot of the QIAamp DSP DNA FFPE Tissue Kit. DNA was extracted and tested at T0, then at T1 (T0+52 weeks), T2 and T3, which spanned an additional eight weeks after T1. The results obtained during this study provide evidence that FFPE NSCLC FNA samples are stable for at least 56 weeks when stored in the correct conditions.

## Interfering substances

This study was designed to demonstrate that the presence of a potentially interfering substance would not produce any false positive or false negative results when testing was performed using the *therascreen* KRAS RGQ PCR Kit. Eight (8) potentially interfering substances from the DNA extraction process were identified: paraffin wax, xylene, ethanol, Buffer ATL, Proteinase K, Buffer AL, Buffer AW1, and Buffer AW2. Each substance was tested using DNA extracted from eight FFPE Cell Lines, representing each of the seven mutations detected by the *therascreen* KRAS RGQ PCR Kit, and a wild type sample. The mutation samples were tested at a level corresponding to approximately three times the limit of detection (3xLOD). Both analytes (mutation and wild-type samples) were spiked with each of the eight potential interfering substances at three different levels: the highest expected carry over (1x), ten-times the highest expected carry over (10x) and one hundred-times the highest expected carry over (100x). To act as a negative control, both analytes were also spiked with Buffer ATE, the final elution buffer in the DNA extraction process. The study demonstrated that the substances identified from the FFPE DNA extraction kit which might carry over into *therascreen* KRAS RGQ PCR Kit did not have any adverse effect on the performance of the assay at the 1x level of interferent; the correct mutation call was always given and the presence of the interfering substance did not have a statistically significant effect on difference in  $\Delta C_T$  means for the majority of sample conditions tested (58 out of 64 conditions, at 1x level). For the six samples that did show a statistically significant difference, the observed difference in the means for each sample was within the study acceptance criterion of  $\pm 2 \times SD$  (SD estimate taken from a reproducibility study).

An additional study was performed to assess the impact of Hemoglobin (Hb) on the *therascreen* KRAS RGQ PCR Kit. In this study, procured clinical resection samples for the 12ALA, 12ASP, 12ARG, 12VAL, 12CYS, and 13ASP mutations were used. A 12SER clinical sample was not assessed due to the rarity of the mutation. A clinical KRAS wild type FFPE sample was incorporated into the study sample set to assess any potential interference in samples with a mutation negative status. Test samples were spiked with Hb at two different

concentrations; half the highest expected carry over (0.5x) and the highest expected carry over (1x). The recommended test concentration (1x) was taken from CLSI EP07-A2 as 2g/L. This study demonstrated that the detection of the 12ASP, 12ARG, 12VAL, 12CYS, and 13ASP mutations by the *therascreen* KRAS RGQ PCR Kit is not impacted by the potential interferant Hemoglobin. Detection of the 12ALA mutations by the KRAS kit however is impacted at a concentration of 0.50 µg/µL Hb or higher.

## Guardband studies

The objective of the guardbanding studies was to establish the robustness of the KRAS Kit. Changes were assessed for any potential effects on mutation reporting. The following studies were conducted to assess the robustness of the KRAS Kit.

### Varying Proteinase K Digestion Times

The objective of this study was to provide guardband study data demonstrating the robustness of the *therascreen* KRAS RGQ PCR System to varying proteinase K digestion times (50, 55, 60, 65 and 70 minutes). Eight non-small cell lung cancer (NSCLC) samples, representing each of the seven mutations detected by the KRAS Kit along with one wild type (WT) (four FFPE cell lines and four clinical FFPE NSCLC samples), were extracted using the FFPE Extraction Kit and tested (6 replicates) using one lot of the KRAS Kit NSCLC. The DNA input level of the samples was determined using the KRAS Kit Control Reaction mix. Mutant samples were tested using the Control Reaction mix and relevant Mutation Reaction mix; WT samples were tested using all eight reactions of the KRAS Kit. The  $\Delta C_T$  values (the difference in FAM  $C_T$  values between a Mutation Reaction and the Control Reaction) and mutation calls for all samples were obtained at each digestion time point.

At the different Proteinase K digestion time points of 55, 60, and 65 minutes, all samples were called with 100% correct mutation calls, demonstrating the robustness of the KRAS System. Overall, varying Proteinase K digestion times (50 min – 70 min) had no significant effect upon

the performance of the KRAS NSCLC system. For the entire study, 238/239 valid samples gave the correct mutation call with a single valid WT replicate giving a 12ASP mutation result at 70 minutes. Since the five other replicates for this sample all gave the expected WT call, no investigation was initiated.

An additional study was also performed assessing the 12ARG mutation (using a human lung cell line FFPE sample) in order to address the deficiencies in the initial study where a pancreatic cell line was used to represent the 12ARG mutation. An FFPE cell line sample which represented the 12ARG mutation detected by the KRAS Kit, was tested in this study. Similar to the study described above, the samples processed for 55, 60, 65, and 70 minutes were assessed. All reaction replicates (144) yielded the correct call.

## Guardband Study on Volumetric Tolerance

The objective of this study was to determine the tolerance of the *therascreen* KRAS Kit to variations in pipetting volumes. Cell lines were used for these studies. This study used eight FFPE cell line samples (12ALA, 12ASP, 12ARG, 12CYS, 12SER, 12VAL, 13ASP, and WT), Positive Control (PC) and No template Control (NTC). The volume of each PCR component (i.e., each reaction mix, sample or Taq polymerase) of the KRAS Kit was varied individually and incrementally up to approximately  $\pm 20\%$  while all other components were used at the standard volumes for the kit. Each variable was considered to be a test condition (TC). Each run was set up in the standard manner, with the exception of the pipetting volumes. The volumes of reagents used for each run were varied so that in total 23 test conditions were analyzed. This guardband study demonstrated that the *therascreen* KRAS RGQ PCR System is robust up to approximately  $\pm 20\%$  in varying pipette volumes for all assays other than 12ASP. When the volume of each PCR component of the KRAS Kit was varied individually and incrementally while all other components were used at the standard volumes, there was no change in mutation call and all differences in mean  $\Delta C_T$  were within  $\pm 2x$  the intermediate precision observed in Repeatability and Reproducibility for all assays, other than 12ASP. The result obtained with the 12ASP assay with the volumetric tolerance level for  $-21\%$  Taq did not

pass the acceptance criteria. The 12ASP sample met the acceptance criteria for  $\pm 8\%$  volumetric tolerance; therefore, this level was set for this reaction.

An additional guardband study was also performed assessing the 12ARG mutation (using a human lung cell line FFPE sample) in order to address the deficiencies in the initial study where a pancreatic cell line was used to represent the 12ARG mutation. An FFPE Cell Line sample which represented the 12ARG mutation detected by the KRAS Kit, was tested in this study. The sample was tested with all 23 test conditions, in triplicate. In order to recreate conditions most likely to result in a false positive or false negative result, the volumes of multiple components (Reaction Mix, *Taq*, and Sample) were altered simultaneously. The acceptance criterion for the study was that the differences in the mean delta  $C_T$  values between the different PCR component levels should either be not significantly different from zero or the estimate should be less than or equal to twice the intermediate precision value calculated during the Repeatability and Reproducibility study. All results fulfilled these requirements. This Guardband study demonstrated that the KRAS Kit is robust enough to tolerate volumetric reagent changes up to  $\pm 20\%$  (when all other factors are constant) due to pipetting error.

# Clinical Performance

The *therascreen* KRAS RGQ PCR Kit is designed to specifically detect 7 *KRAS* mutations in codons 12 and 13 of the *KRAS* gene. It is not designed to specifically detect the wild-type sequence at these codons. The results of the test are reported out as “[mutation name] Detected” and “No Mutation Detected.” In clinical studies presented below, *KRAS* mutation positive results are those patients whose tumor tissue was positive for one or more of the 7 mutations detected by the *therascreen* KRAS RGQ PCR Kit (G12A, G12D, G12R, G12C, G12S, G12V, G13D). *KRAS* mutation-negative (wild-type) refers to those patients whose tumor tissue was negative for the 7 mutations detected by the *therascreen* KRAS RGQ PCR Kit (i.e., the sample may, in fact, harbor mutations in the *KRAS* gene not identified by the *therascreen* KRAS RGQ PCR Kit).

## Clinical study supporting use with Erbitux (cetuximab)

A clinical performance study was conducted to generate data to support the clinical utility of the *therascreen* KRAS RGQ PCR Kit as a companion diagnostic test that enables selection of patients for treatment with Erbitux (cetuximab). The safety and effectiveness of Erbitux (cetuximab) has been demonstrated in the CA225025 study. CA225025 was a multicenter, open-label, randomized clinical trial conducted in 572 patients with EGFR-expressing, previously treated, recurrent metastatic CRC (mCRC). Patients were randomized (1:1) to receive either Erbitux (cetuximab) plus best supportive care (BSC) or BSC alone. Erbitux (cetuximab) was administered as a 400 mg/m<sup>2</sup> initial dose, followed by 250 mg/m<sup>2</sup> weekly until disease progression or unacceptable toxicity.

Of the 572 randomized patients, the median age was 63 years; 64% were male, 89% were Caucasian, and 77% had baseline ECOG performance status of 0–1. Demographics and baseline characteristics were similar between study arms. All patients were to have received

and progressed on prior therapy including an irinotecan-containing regimen and an oxaliplatin-containing regimen.

KRAS mutation status was available for 453/572 (79%) of the patients: 245 (54%) patients had KRAS mutation-negative tumors and 208 (46%) patients had KRAS mutation-positive tumors when assessed by the *therascreen* KRAS RGQ PCR Kit.

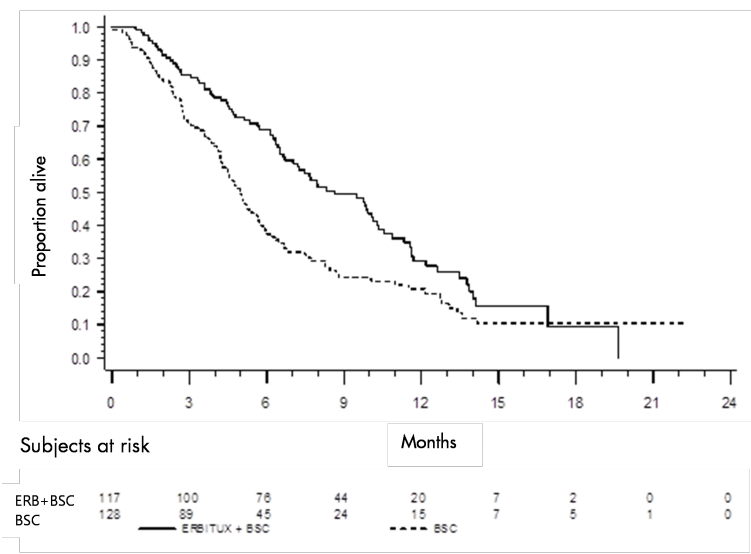
The main outcome measure of the study was overall survival (OS). For the KRAS mutation-negative (wild-type) population, median survival time (95% CI) was 8.6 (7.0, 10.3) months in the Erbitux (cetuximab)+BSC group and 5.0 (4.3, 5.7) months in the BSC group. The OS hazard ratio of Erbitux (cetuximab)+BSC over BSC was 0.63. The 95% confidence interval (CI) was (0.47, 0.84).

For the KRAS mutation-positive population, median survival time was 4.8 (3.9, 5.6) months in the Erbitux (cetuximab)+BSC group and 4.6 (3.6, 4.9) months in the BSC group. The hazard ratio was 0.91 with 95% CI (0.67, 1.24). Results are presented in Table 46 and Figure 3.

**Table 46. Overall survival in previously treated EGFR-expressing metastatic colorectal cancer (all randomized and KRAS status)**

	All randomized		Wild-type KRAS mutation-negative		KRAS mutation-positive	
	Erbitux+BSC N=287	BSC N=285	Erbitux+BSC N=117	BSC N=128	Erbitux+BSC N=108	BSC N=100
Media (months) (95% CI)	6.1 (5.4, 6.7)	4.6 (4.2, 4.9)	8.6 (7.0, 10.3)	5.0 (4.3, 5.7)	4.8 (3.9, 5.6)	4.6 (3.6, 4.9)
Hazard ratio (95% CI)	0.77 (0.64, 0.92)		0.63 (0.47, 0.84)		0.91 (0.67, 1.24)	
p-value*	0.0046		–		–	

\* Based on the stratified log-rank test.



**Figure 3. Kaplan-Meier curve for overall survival in patients with *KRAS* mutation-negative (wild type) metastatic colorectal cancer.**

Overall survival rates based on Kaplan-Meier estimates at months 6 and 12 were higher for the Erbitux (cetuximab)+BSC group than the BSC group for the *KRAS* wild-type subset. This advantage was not observed in the *KRAS* mutant subset.

### Clinical study supporting use with Vectibix (panitumumab)

A clinical performance study was conducted to generate data to support the clinical utility of the *therascreen* *KRAS* RGQ PCR Kit as a companion diagnostic test that aids in the identification of patients for treatment with Vectibix (panitumumab). The objective of the study was to assess whether *KRAS* mutation status as determined by the *therascreen* *KRAS* RGQ PCR Kit can be used to select patients with mCRC who will benefit from Vectibix (panitumumab) treatment. The clinical trial 20050203 was a multicenter, prospective, open-

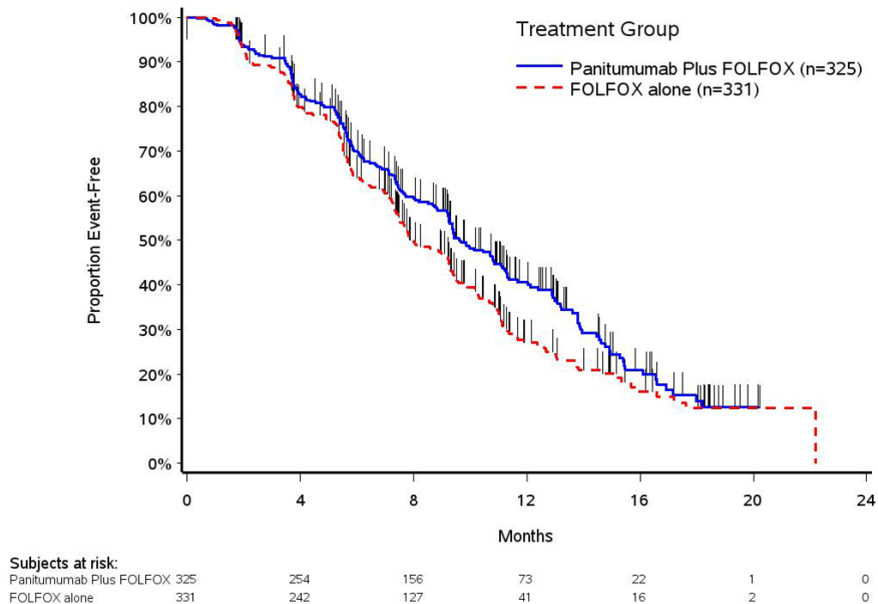
label, randomized phase 3 study to assess the efficacy of panitumumab in combination with oxaliplatin, 5-fluorouracil (5-FU) and leucovorin (FOLFOX) vs. FOLFOX alone in patients with previously untreated, recurrent mCRC.

Banked tumor samples from patients in study 20050203 were tested with the *therascreen* KRAS RGQ PCR Kit to identify two subgroups: *KRAS* mutation-positive (mutant *KRAS*) and *KRAS* mutation-negative (wild-type *KRAS*), according to whether at least one or none of 7 *KRAS* mutations in codons 12 and 13 of exon 2 in the *KRAS* gene was detected. In retrospective analyses, efficacy data from study 20050203 were stratified by *KRAS* subgroup. The primary objective of the *KRAS* analysis was to assess whether an overall improvement in PFS for Vectibix (panitumumab) plus FOLFOX relative to FOLFOX alone was significantly greater among subjects with *KRAS* wild-type tumors compared to subjects with *KRAS* mutant tumors.

The prespecified primary efficacy endpoint was progression-free survival (PFS) in the group of patients (n = 656) with wild-type *KRAS* mCRC as assessed by a blinded independent central review of imaging. Other key efficacy endpoints included OS and ORR. The efficacy results in patients with wild-type *KRAS* mCRC are presented in Table 47 and Figure 4.

**Table 47. Efficacy results in patients with wild-type *KRAS* mCRC**

PFS					
	Wild-type <i>KRAS</i> pop- ulation	Median (months) (95% CI)	Hazard ratio (95% CI)	p-value	ORR (95% CI)
Panitumumab plus FOLFOX	N=325	9.6 (9.2, 11.1)	0.80 (0.66, 0.97)	0.02	54% (48%, 59%)
FOLFOX alone	N=331	8.0 (7.5, 9.3)			47% (41%, 52%)



**Figure 4. Kaplan-Meier plot of progression-free survival (PFS) in patients with wild-type *KRAS* mCRC.**

Among patients with *KRAS* mutant tumors, median PFS was 7.3 months (95% CI: 6.3, 8.0) in the 221 patients receiving Vectibix (panitumumab) plus FOLFOX versus the median PFS of 8.8 months (95% CI: 7.7, 9.4) in the 219 patients who received FOLFOX alone (HR = 1.29, 95% CI: 1.04, 1.62). Median OS was 15.5 months (95% CI: 13.1, 17.6) in patients receiving Vectibix (panitumumab) plus FOLFOX versus the median OS of 19.3 months (95% CI: 16.5, 21.8) in patients who received FOLFOX alone (HR = 1.24, 95% CI: 0.98, 1.57).

An exploratory analysis of OS with updated information based on events in 82% of patients with wild-type *KRAS* mCRC estimated the treatment effect of Vectibix (panitumumab) plus FOLFOX compared with FOLFOX alone. Median OS among 325 patients with wild-type *KRAS* mCRC who received Vectibix (panitumumab) plus FOLFOX was 23.8 months (95% CI: 20.0,

27.7) versus 19.4 months (95% CI: 17.4, 22.6) among 331 patients who received FOLFOX alone (HR = 0.83, 95% CI: 0.70, 0.98). Results are shown in Figure 5.

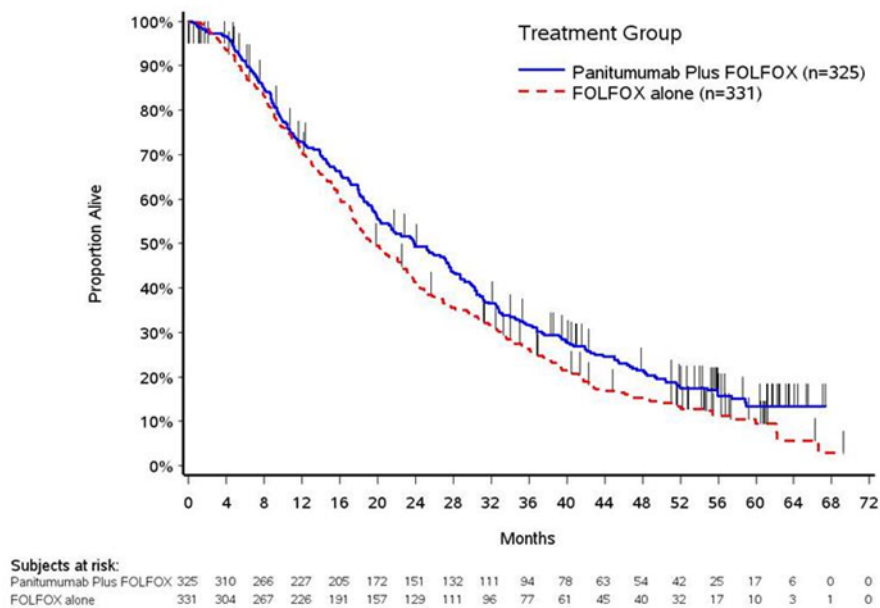


Figure 5. Kaplan-Meier Plot of overall survival (OS) in patients with Wild-type *KRAS* mCRC.

## Clinical study supporting use of LUMAKRAS (sotorasib) for NSCLC

A clinical performance study was conducted to demonstrate the clinical validity of the *therascreen* KRAS RGQ PCR Kit as a companion diagnostic test to aid in the identification of KRAS G12C positive NSCLC patient for treatment with LUMAKRAS (sotorasib). The objective of the study was to assess whether G12C mutation status, as determined by the *therascreen* KRAS RGQ PCR Kit, can be used to select patients with advanced NSCLC who will benefit

from LUMAKRAS (sotorasib) treatment. The clinical trial 20170543 was an open-label, multicenter, phase 1/2 study designed to evaluate the efficacy and safety of LUMAKRAS (sotorasib) in adult subjects with advanced solid tumors that harbor the *KRAS* G12C mutation. Data from the primary analysis of the NSCLC phase 2 portion of this study has been used to support the clinical validity of the *therascreen* *KRAS* RGQ PCR Kit as a companion diagnostic test. Enrollment was restricted to subjects with *KRAS* G12C-mutated NSCLC as assessed by a local laboratory result, which was confirmed by central testing using the *therascreen* *KRAS* RGQ PCR Kit.

The primary end point of the NSCLC phase 2 portion of this study was to evaluate tumor objective response rate (ORR) assessed by Response Evaluation Criteria in Solid Tumors (RECIST), version 1.1, criteria of LUMAKRAS (sotorasib) as monotherapy in subjects with *KRAS* G12C-mutated advanced tumors.

Of a total of 126 subjects with NSCLC, 124 subjects were included in the full analysis set. Two subjects were excluded as they did not have  $\geq 1$  measurable lesion according to blinded independent centralized review (BICR). The primary endpoint of ORR (complete response + partial response) measured by computed tomography or magnetic resonance imaging and assessed per RECIST 1.1 by BICR laboratory for subjects with *KRAS* G12C-mutated NSCLC was 36% (45 of 124 subjects; 95% CI: 28–45%); two (2) subjects (2%) achieved complete response and 43 subjects (35%) achieved partial response.\* The median duration of response (DOR) by the Kaplan-Meier method was 10 months (with a range of 1.3+, 11.1).

## Clinical study supporting use of Krazati (adagrasib) for NSCLC

A bridging study was conducted to demonstrate the clinical efficacy of the *therascreen* *KRAS* RGQ PCR Kit when used as a companion diagnostic to identify NSCLC patients for treatment with Krazati (adagrasib) based on a *KRAS* G12C mutation detected test result. The

\*Based on 01 December 2020 data cut.

results were compared with the clinical efficacy observed in Cohort A of a clinical trial 849-001. Clinical efficacy was evaluated by assessing the ORR for *KRAS* G12C mutation detected, *KRAS* G12C mutation non-detected and *KRAS* G12C mutation non-evaluable subjects separately.

The clinical trial 849-001 was a phase 1/2 multiple expansion cohort trial of Krazati (adagrasib) in patients with advanced solid tumors with *KRAS* G12C mutation. The primary objective of the trial was to characterize the safety and tolerability of Krazati (adagrasib) in patients having advanced solid tumor malignancies with *KRAS* G12C mutation and to evaluate the pharmacokinetics of Krazati (adagrasib). Cohort A enrolled patients with advanced NSCLC with *KRAS* G12C mutation who had previously received treatment with a platinum-based regimen and an immune checkpoint inhibitor. The primary endpoint for evaluation of efficacy was ORR, in accordance with RECIST version 1.1.

Of the total of 116 subjects from Cohort A which were enrolled by multiple clinical trial assays (CTA), 12 subjects were not sent for *KRAS* G12C testing as they had insufficient tumor for testing and were not included in any subsequent analysis. In addition to testing Cohort A specimens as part of the bridging study, 114 procured clinical *KRAS* G12C negative specimens were tested with the *therascreen* *KRAS* RGQ PCR Kit. In total, FFPE tissue specimens from 218 unique subjects (104 from Cohort A and 114 procured) were sent to a central laboratory for *KRAS* G12C testing with the *therascreen* *KRAS* RGQ PCR Kit.

Two specimens were from the same procured subject, therefore, in total 219 specimens were tested for *KRAS* G12C mutation status. Three samples from Cohort A had either no tumor or insufficient sample for the testing. Of the 216 testable samples, 210 produced evaluable results. Of the 218 unique subjects, 209 produced evaluable results. None of the procured clinical *KRAS* G12C negative specimens tested *KRAS* G12C positive when testing with the *therascreen* *KRAS* RGQ PCR Kit.

Based on the clinical bridging study, the positive percent agreement (PPA) and the negative percent agreement (NPA) between the *therascreen* KRAS RGQ PCR Kit (CDx) and the clinical trial enrollment assays (CTA) were calculated (PPA: 88.78%; NPA: 100%) (Table 48). An NPA of 100% indicated that final estimated drug efficacy (ORR) for the *KRAS* G12C mutation positive patients tested by CDx in the intended use population is same as the estimated drug efficacy of the CDx-positive patients observed in Cohort A primary efficacy population in the 849-001 clinical trial.

**Table 48. Concordance between *therascreen* KRAS RGQ PCR Kit (CDx) and clinical trial enrollment assays (CTA)**

	CTA Positive, n	CTA negative, n	Total
CDx Positive, n	87	0	87
CDx Negative, n	11	111	122
Total	98	111	209
Positive Percent Agreement [95% CI(1)]	88.78% (80.80%, 94.26%)		
Negative Percent Agreement [95% CI(1)]	100.00% (96.73%, 100%)		

(1)The 95% CI is calculated using the Exact (Clopper-Pearson) method

Sensitivity analysis to evaluate the robustness of the clinical efficacy estimate against the missing *therascreen* KRAS G12C test results was performed using the multiple imputation methods. The clinical efficacy (ORR) for the *therascreen* KRAS G12C mutation positive subjects in the device intended use population was estimated under different assumed scenarios based on observed and imputed results. This sensitivity analyses demonstrated the robustness of the estimated clinical efficacy.

Efficacy of the *therascreen* KRAS RGQ PCR Kit, in identifying patients as *KRAS* G12C mutation detected for treatment with Krazati (adagrasib) has been demonstrated. The primary endpoint of ORR in *KRAS* G12C mutation detected patients with measurable disease was

43% (36/83, 95% CI: (33%, 55%)) which exceeded the hypothesized response rate of 23% reported with standard care and met the study acceptance criteria.

## Clinical study supporting use of Krazati (adagrasib) for CRC

A bridging study was conducted to evaluate the clinical utility of the *therascreen* KRAS RGQ PCR Kit when used as a companion diagnostic (CDx) to identify patients diagnosed with metastatic CRC (mCRC) for treatment with Krazati (adagrasib) with cetuximab based on a positive *KRAS* G12C mutation test result. The results of the bridging study were compared with the clinical efficacy observed in a Phase 1/2 clinical trial conducted by Mirati Therapeutics (849-001, KRYSTAL 1). Clinical efficacy was evaluated by assessing the overall response rate (ORR) of subjects enrolled into the Phase 1 sub-study and Phase 2 cohort G. Subjects with *KRAS* G12C mutation detected, *KRAS* G12C mutation not detected and non-evaluable/non-testable results were evaluated separately.

The clinical trial 849-001 was a phase 1/2 multiple expansion cohort trial of Krazati (adagrasib) with cetuximab in patients with advanced solid tumors with *KRAS* G12C mutation. CRC patients were enrolled into the Phase 1 sub-study, the Phase 1b dose optimization cohort and Phase 2 Cohort G. Patients enrolled in Phase 2, Cohort G had been previously treated with at least a fluoropyrimidine, oxaliplatin, irinotecan, and a VEGF/VEGFR inhibitor. The primary objective of the trial was to characterize the safety and tolerability of Krazati (adagrasib) in patients having advanced solid tumor malignancies with *KRAS* G12C mutation and to evaluate the pharmacokinetics of Krazati (adagrasib). ORR based on criteria in RECIST version 1.1 was the primary endpoint for evaluating clinical efficacy.

Patients were enrolled into 849-001 based on multiple *KRAS* mutation detection assays other than the QIAGEN *therascreen* KRAS RGQ PCR Kit; these assays were the Clinical Trial Assay (CTA). The bridging study was conducted to establish concordance between the *therascreen*

KRAS Kit (the CDx) and the CTA used in the trial, as determined by a comparison of ORR for KRAS G12C+/- cohorts.

Samples from 121 KRAS G12C+ subjects with mCRC tested with a CTA were enrolled into Phase 1 sub-study (32 subjects), Phase 1b dose optimization (27 subjects) and Phase 2 Cohort G (62 subjects) of the Mirati study 849-001. Of these 121 subjects, 35 samples (14 Phase 1, 7 Phase 1b and 14 Phase 2) were not testable, either due to insufficient tumor tissue or no consent for further testing and were not evaluated using the *therascreen* KRAS kit or included in efficacy analysis. The 86 testable samples from Phase 1/2 were supplemented with an additional 91 mCRC samples with KRAS G12C not detected results that were procured from commercial vendors. In total, FFPE tissue specimens from 177 unique subjects (86 from Phase 1/2 of Mirati study 849-001 and 91 procured) were sent to a central laboratory for KRAS G12C testing with the *therascreen* KRAS RGQ PCR Kit. Of the 177 samples 171 produced evaluable results.

Based on the clinical bridging study, the positive percent agreement (PPA) and the negative percent agreement (NPA) between the *therascreen* KRAS RGQ PCR Kit (CDx) and the clinical trial enrollment assays (CTA) were calculated (PPA: 92.50%; NPA: 100%) as shown in Table 49. Concordance between CTA and CDx is based on CTA as a reference method.

**Table 49. Concordance between *therascreen* KRAS RGQ PCR Kit (CDx) and clinical trial enrollment assays (CTA)**

	CTA Positive, n	CTA negative, n	Total
CDx Positive, n	74	0	74
CDx Negative, n	6	91	97
Total	80	91	171
Positive Percent Agreement [95% CI(1)]	92.50% (84.39%, 97.20%)		
Negative Percent Agreement [95% CI(1)]	100.00% (96.03%, 100%)		

(1)The 95% CI is calculated using the Exact (Clopper-Pearson) method

Sensitivity analysis to evaluate the robustness of the clinical efficacy estimate against the missing *therascreen* KRAS G12C test results was performed using multiple imputation methods. The clinical efficacy (ORR) for the *therascreen* KRAS G12C mutation positive subjects in the device intended use population was estimated under different assumed scenarios based on observed and imputed results. This sensitivity analyses demonstrated the robustness of the estimated clinical efficacy.

Effectiveness of the *therascreen* KRAS RGQ PCR Kit (CDx), in identifying mCRC patients as KRAS G12C mutation detected for treatment with Krazati (adagrasib) and cetuximab, has been demonstrated using subject from the primary efficacy population. The primary endpoint of ORR in CDx KRAS G12C mutation detected patients with measurable disease in the bridging study was 34.6% (19/55, 95% CI: 22.2%, 48.6%) This value exceeded the acceptance criteria from the KRYSTAL-1 study (i.e., the hypothesized response rate of 5% reported with standard care and was comparable to the ORR value seen in the KRYSTAL-1 study (34.0%).

## Clinical study supporting use of LUMAKRAS (sotorasib) for CRC in combination with panitumumab

Amgen and QIAGEN partnered to evaluate the *therascreen* KRAS RGQ PCR Kit for a new indication: a companion diagnostic test that aids in the identification of colorectal cancer (CRC) patients with *KRAS* G12C mutations, who may benefit from treatment with sotorasib in combination with panitumumab. This study was designed to utilize the *therascreen* KRAS RGQ PCR Kit as a screening test in the phase 3 Amgen clinical study (Protocol No. 20190172) to identify CRC patients with *KRAS* G12C mutation positive tumors. The data from the study was to be used to determine the drug-device efficacy to support future regulatory submissions for the device-drug combination.

A total of 219 subjects were screened for enrollment into this Amgen study number 20190172 and 160 were randomized to either the sotorasib 240 mg + panitumumab group (53 subjects), sotorasib 960 mg + panitumumab group (53 subjects), or control (trifluridine and tipiracil or regorafenib) group (54 subjects). Three subjects (5.6%) never received investigational product in the control group (ineligibility determined for 1 subject, subject request for 1 subject, and other reason for 1 subject [all 1.9%]), while all subjects in both sotorasib + panitumumab groups received investigational product. Of the 219 subjects, 211 were tested with the CDx (8 screen failed prior to CDx testing). All of the 160 enrolled and randomized subjects had a G12C positive result with the CDx. Of the remaining 51 screen fail subjects, 27 had CDx G12C positive results, 12 had G12C negative results, and 9 were not evaluable and 3 had invalid results.

All samples had a positive local test result prior to testing with the CDx. PPA between the CDx and local results was 94.0% (187/199). The PPA between the CDx and the different local test methodologies used in the study can be seen in Table 50. No local test negative samples from the study were available for testing with the CDx. However, NPA for the CDx in CRC specimens has been established in the clinical study supporting use of Krazati (adagrasib) for CRC.

Table 50. Concordance between *therascreen* KRAS RGQ PCR Kit (CDx) and clinical trial enrollment assays (CTA)

	CTA Positive, n	CTA negative, n*	Total
CDx Positive, n	187	0	187
CDx Negative, n	12	91	103
Total	199	91	290
Positive Percent Agreement [95% CI <sup>(†)</sup> ]	94.0% (89.7%, 96.8%)		
Negative Percent Agreement [95% CI <sup>(†)</sup> ]	100.0% (96.0%, 100.0%)		

\* Calculated using the data from 91 CTA negative samples from the clinical study supporting use of Krazati (adagrasib) for CRC.

† The 95% CI is calculated using the Exact (Clopper-Pearson) method.

Data cut-off date for the primary analysis of Progression-free survival (PFS) was 19 June 2023.

A total of 97 PFS events were reported by the data cut-off date (19 June 2023) . The median (95% CI) PFS was 3.9 months (3.6, 5.8) in the sotorasib 240 mg + panitumumab group, compared with 2.0 months (1.9, 3.9) in the control group. The median (95% CI) PFS was 5.6 months (4.2, 6.3) in the sotorasib 960 mg + panitumumab group, compared with 2.0 months (1.9, 3.9) in the control group.

The hazard ratio (HR) (95% CI) for disease progression or death was 0.6 (0.4, 1.0; 2-sided p-value = 0.06) for the sotorasib 240 mg + panitumumab versus the control, and 0.5 (0.3, 0.8; 2-sided p-value = 0.011) for the sotorasib 960 mg + panitumumab versus the control , demonstrating a statistically significant benefit in PFS in the sotorasib 960 mg + panitumumab treatment group.

The PFS results are consistent with those observed in the analysis of the Full Analysis Set (FAS) .

In conclusion, for the *KRAS* population, as in the Full Analysis Set, Sotorasib 960 mg + panitumumab showed a statistically significant improvement in PFS, and a trend toward improved OS, when compared to standard of care in a highly pre-treated population, for subjects with *KRAS* p.G12C-mutated mCRC as determined using the *therascreen* *KRAS* RGQ PCR Kit.

For more information regarding Erbitux, Vectibix, LUMAKRAS and Krazati indications, refer to the most recent drug labels at [www.accessdata.fda.gov/scripts/cder/drugsatfda/index.cfm](http://www.accessdata.fda.gov/scripts/cder/drugsatfda/index.cfm).

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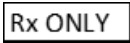







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# Symbols

The following symbols appear in the instructions for use or on the packaging and labeling:

Symbol	Symbol definition
	Contains reagents sufficient for <N> reactions
	Use by date
	Prescription use only
	In vitro diagnostic medical device
	Catalog number
	Lot number
	Material number (i.e., component labeling)
	Contains
	Components
	Number
Rn	R is for revision of the Instructions for Use and n is the revision number

Symbol

Symbol definition



Temperature limit



Manufacturer



Consult instructions for use



Keep away from sunlight

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For technical assistance and more information, please see our Technical Support Center at [www.qiagen.com/Support](http://www.qiagen.com/Support), call 1-800-362-7737/800-426-8157, or contact one of the QIAGEN Technical Service Departments or local distributors (see back cover or visit [www.qiagen.com](http://www.qiagen.com)).

# Appendix: Installation of the Rotor-Gene Q *therascreen* KRAS Assay Package

The *therascreen* KRAS RGQ PCR Kit is designed for use with the Rotor-Gene Q MDx (US) with a 72-well rotor. The *therascreen* KRAS Assay Package is available separately for download at [www.qiagen.com](http://www.qiagen.com).

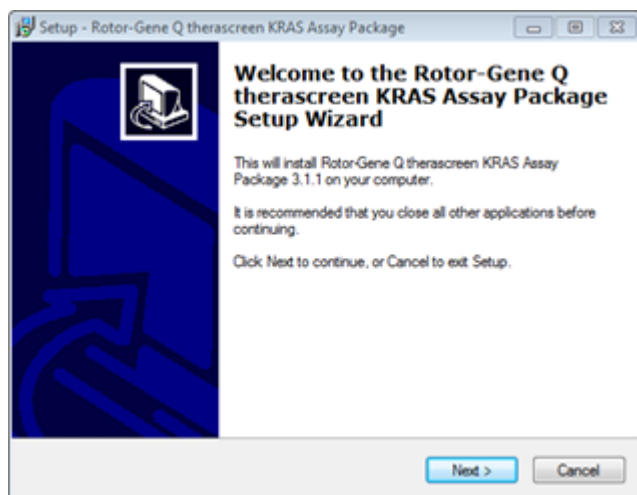
**Note:** The Rotor-Gene Q *therascreen* KRAS Assay Package will work with the corresponding Rotor-Gene Q Software version 2.3.5 . Make sure the correct version of the Rotor-Gene Q software is installed before proceeding with the *therascreen* KRAS Assay Package installation.

The package includes “*therascreen* KRAS QC Locked Template” and “*therascreen* KRAS Locked Template.” The Assay Package also includes printable plate maps that can be used to record the experiments and run templates that define the PCR protocols for FFPE sample preparation using the QIAamp DSP DNA FFPE Tissue Kit, DNA sample assessment using the *therascreen* KRAS RGQ PCR Kit and detection of KRAS mutations using the *therascreen* KRAS RGQ PCR Kit.

Follow this procedure to install the *therascreen* KRAS Assay Package:

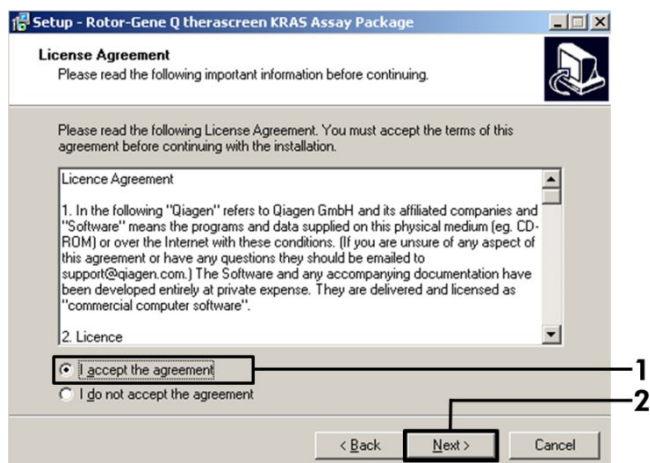
1. Download the Rotor-Gene Q **KRAS Assay Package version 3.1.1** from [www.qiagen.com](http://www.qiagen.com).
2. Transfer the Assay package to the laptop connected to the Rotor-Gene Q MDx instrument using a virus-free removable storage.
3. Double-click ***therascreen\_KRAS\_Assay\_Package\_3.1.1.exe*** to start the installation.

The setup wizard will appear.



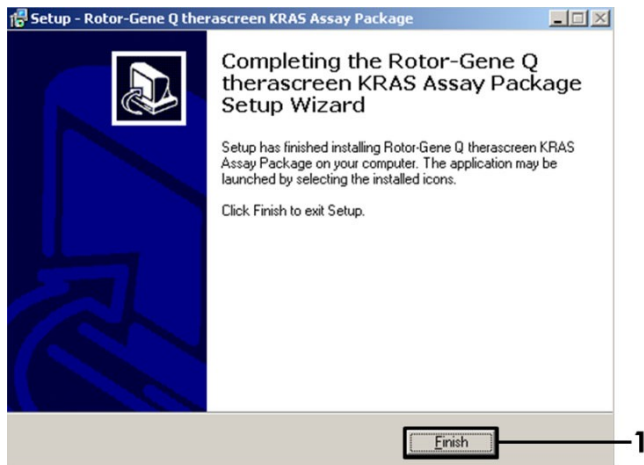
4. Click **Next** to continue.

The License Agreement dialog box opens.



5. Read the License Agreement in the License Agreement box and check **I accept the agreement** (1).
6. Click **Next** (2) to continue.

The template setup will start automatically and a final Setup dialog box will appear.



7. Click **Finish** (1) to exit the setup wizard.
8. Restart the computer.

Shortcuts to both the therascreen KRAS QC Locked Template and therascreen KRAS Locked Template will be generated automatically and appear on the desktop.

# Ordering Information

Product	Contents	Cat. no.
<i>therascreen</i> KRAS RGQ PCR Kit (24)	For 24 reactions: 1 Control Assay, 7 Mutation Assays, Positive Control, Water, Taq DNA Polymerase	870021
<i>therascreen</i> KRAS Assay Package version 3.1.1 (CD)	Software protocol package for use with the <i>therascreen</i> KRAS RGQ PCR Kit and the QIAGEN Rotor-Gene Q MDx (US) instrument (compatible with Rotor Gene Q software version 2.3)	9023818
<i>therascreen</i> KRAS Assay Package CD	Software protocol package for use with the <i>therascreen</i> KRAS RGQ PCR Kit and Rotor-Gene Q MDx 5plex HRM instrument with a 72-well rotor	9023675
<b>Rotor-Gene Q and accessories</b>		
Rotor-Gene Q MDx Platform (US)	Real-time PCR cycler, laptop computer, software, accessories, 1-year warranty on parts and labor	9002035
Rotor-Gene Q MDx System (US)	Real-time PCR cycler, laptop computer, software, accessories, 1-year warranty on parts and labor, installation and training	9002036
Rotor-Gene Q MDx 5plex HRM	Real-time PCR cycler and High Resolution Melt analyzer with 5 channels (green, yellow, orange, red, crimson) plus HRM channel, laptop computer, software, accessories, 1-year warranty on parts and labor; installation and training not included	9002032
Rotor-Gene Q MDx	Aluminum block for manual reaction setup with a single-channel pipet in 72 x 0.1 mL tubes	9002033
Loading Block 72 x 0.1 mL Tubes	Aluminum block for manual reaction setup with a single-channel pipet in 72 x 0.1 mL tubes	9018901

Product	Contents	Cat. no.
Strip Tubes and Caps, 0.1 mL (250)	250 strips of 4 tubes and caps for 1000 reactions	981103
Strip Tubes and Caps, 0.1 mL (2500)	10 x 250 strips of 4 tubes and caps for 10,000 reactions	981106
<b>QIAamp DSP DNA FFPE Tissue Kit — for purification of genomic DNA from paraffin-embedded tissues</b>		
QIAamp DSP DNA FFPE Tissue Kit (50)	For 50 DNA preps: QIAamp Mini Spin Columns, Proteinase K, Buffers, Reagents, and Collection Tubes (2 mL)	60404

For up-to-date licensing information and product-specific disclaimers, see the respective QIAGEN kit Instructions for Use. QIAGEN kit Instructions for Use are available at [www.qiagen.com](http://www.qiagen.com) or can be requested from QIAGEN Technical Services or your local distributor.

# Document Revision History

Revision	Description
R14 August 2023	<p>Added a reference to the flag interpretation table in the note regarding actions related to flags for NSCLC indication</p> <p>Updated the action for CRC flag SAMPLE_INT_CTRL_FAIL to remove a dilution step action</p> <p>Updated the action for NSCLC flag SAMPLE_INT_CTRL_FAIL to remove ambiguity in interpretation</p> <p>Updated Table 18 to correct labelling error for the assignment of 12ARG and 12ASP sample data</p> <p>Handbook revision number captured on page 1 and in document revision history section were incorrect for revision 13 of this handbook. This has since been updated in this revision (R14) in the document revision history section</p>
R15, October 2024	<p>Updated Intended Use and Clinical performance sections to add information about Krazati CRC</p> <p>Clarified importance of mixing at multiple steps</p> <p>Clarity added to flags and splitting of flags where actions are different based on their indication</p> <p>Addition of text for storage of FFPE</p> <p>Correction of typographical error 12ASP to 13ASP</p>
R16, October 2025	<p>Updated Intended Use table to include information about CRC for LUMAKRAS in combination with Vectibix</p> <p>Revised statement regarding CRC patients in Summary and Explanation section</p> <p>Revised the Materials Required but Not Provided and Specimen Handling and Storage sections to update information regarding fresh scalpel, razor blade, or similar sharp bladed instrument</p> <p>Included 2 decimal places for 12VAL 3x LOD % CV for Ct values in Table 30</p> <p>Updated amplification efficiency values for 12ARG and 13ASP in Table 46; Table footnote removed</p> <p>Added new sections regarding clinical studies for CRC under Clinical Performance section</p> <p>Added Prescription Use Only symbol</p>

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