



Tutorial

Compare TMB Scores and MSI Statuses from QIAseq Tumor Mutational Burden Panels

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— Sample to Insight —

Compare TMB Scores and MSI Statuses from QIAseq Tumor Mutational Burden Panels

This tutorial uses the capabilities of CLC Genomics Workbench with the Biomedical Genomics Analysis plugin to calculate reliable and consistent TMB score and MSI status values.

QIAGEN offers the QIAseq Tumor Burden Mutation panel assay (DHS-8800Z) covering a significantly larger region of the genome than other Targeted DNA panels and including gene families, which increases the difficulty of variant calling especially with regards to specificity. Through a series of tools and filters, the Identify TMB Status ready-to-use workflow has the ability to accurately call variants and to compute a TMB score (total number of somatic mutations in a defined region of a tumor genome) that can be used for classification as TMB low, intermediate or high. High TMB scores have been shown to be correlated with improved patient response rates to immune check-point inhibitors [A. Stenzinger et al., 2019].

In addition, the DHS-8800Z QIAseq Targeted DNA panel covers loci useful for Microsatellite Instability Status inference. This status measures the statistical variation of the length distribution of several microsatellite loci, and compares the statistical variation of the test sample with a normal samples' baseline (included in QIAGEN Reference Data Set available for download in the Workbench). If the proportion of unstable microsatellite loci is higher than the predefined threshold, then the sample is considered unstable. Many patients with MSI-High tumors have had a positive response to immunotherapy treatments. In addition, The US Food and Drug Administration (FDA) has granted accelerated approval to pembrolizumab for pediatric and adult patients with microsatellite instability (MSI)-High, leading to the first approved treatment for any solid tumor with this biomarker irrespective of the tumor's origin [Chang et al., 2018].

This tutorial covers:

- Importing filtered variant tracks and read mappings into the Workbench.
- Running the Calculate TMB Score tool on adjusted target regions to output TMB Score reports for each sample.
- Running the Detect QIAseq MSI Status workflow on these samples for comparison.

We use a subset of the Identify TMB Status ready-to-use workflow results for 5 samples as example data. Analyses in this tutorial should run within 20 min on a standard laptop. If you wish to run the Identify TMB Status ready-to-use workflow, which takes longer to run, the original reads can be found on [our website](#).

Prerequisites For this tutorial, you must be working with the *CLC Genomics Workbench* with the Biomedical Genomics Analysis plugin installed. How to install plugins is described in the [Workbench manual](#).

Download and import data Go through the following steps to download and import the data into the Workbench.

1. Download the sample data from [our website](#) and save it on your computer. For each sample, we provide:

- A **Read Mapping** of the UMI Reads (📄)
 - A Variant track: The **Filtered variant** track (📄) includes all somatic variants that remained after the filtering performed in the Identify TMB Status Ready-to-Use workflow and that is input Calculate TMB Score tool.
2. Start the workbench.
 3. Import the reads via the toolbar: **Import** (📄) | **Standard Import**.
 4. Select the `TMB_MSI_tutorial.zip` file and leave the option to "Automatic import". Click **Next**.
 5. Select the location in the Navigation Area of your Workbench where the data should be saved, and click **Finish**.

In addition, you will need to import the Reference Data Set needed to run the tool and workflow demoed in this tutorial.

1. Click on the button References in the top right corner of the Workbench.
2. In the QIAGEN Sets tab, under the Reference Data Sets section, choose the QIaseq TMB Panels hg38 and click on **Download** (figure 1).

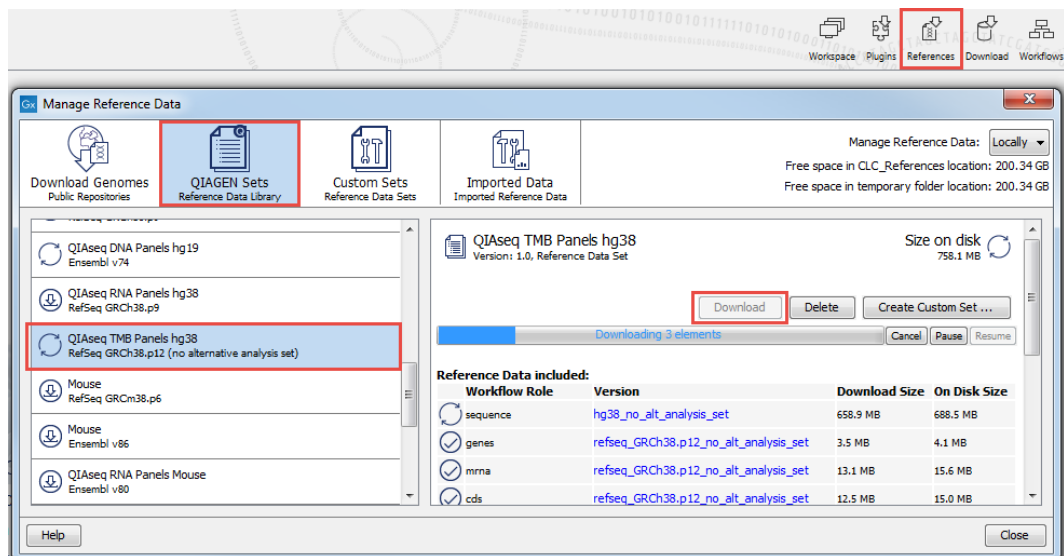


Figure 1: Importing the relevant Reference Data Set.



3. Once imported, the Reference data elements included in the set will be available in the `CLC_References` folder in the Navigation Area.

Run the Calculate TMB Score tool

Calculating TMB score is better done on target regions with coverage 100X. Target regions with insufficient coverage are automatically removed when using the Identify TMB Status ready-to-use workflow. However, when using the Calculate TMB Score on its own, it is recommended to adjust

target regions files before hand. To remove the low coverage regions of the original target region file:

1. Start the Create Mapping Graph tool from the Toolbox:

Toolbox | Track Tools  | Graphs  | Create Mapping Graph 

and choose the 5 read mappings to be run in batch mode as shown in figure 2.

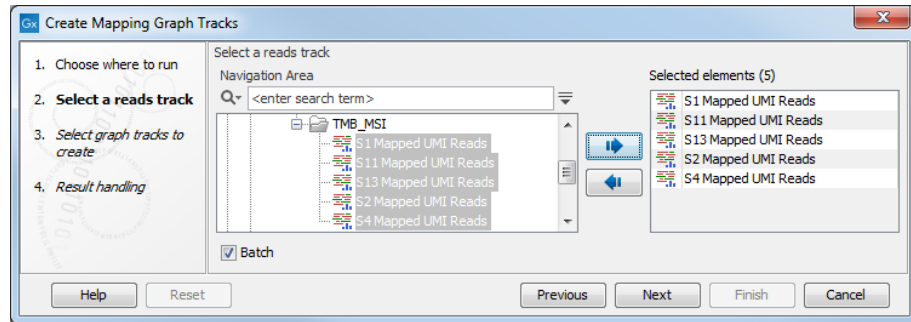


Figure 2: Select the 5 read mappings in batch.

2. Use the default setting for the tool to generate read coverage graph for the mappings.
3. Save the Mapping Graph Tracks in the Navigation Area.
4. Now open the Identify Graph Threshold Areas tool:

Toolbox | Track Tools  | Graphs  | Identify Graph Threshold Areas 

5. Select in batch the Mapping Graph Tracks you just generated (figure 3).

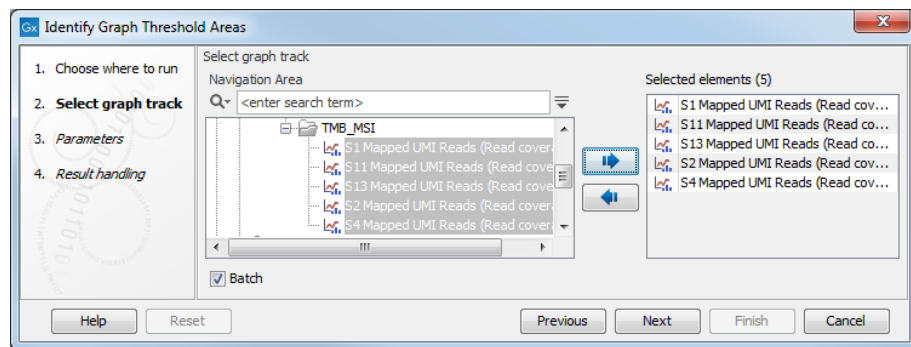


Figure 3: Select the 5 mapping graph tracks in batch.

6. Set the lower threshold at 100 to exclude regions with coverage below 100X, disable the upper threshold and specify the target region reference track for the TMB panel available in the CLC_Reference folder (figure 4). You will find it in the QIAseq TMB Panels hg38 (RefSeq GRCh.38.p12 (no alternative analysis set)) folder, in the subfolder named **target_regions**. Make sure you select the "Reference Data" tab (highlighted in red) to be able to locate easily the reference tracks that belong to a given Reference Data Set. The same tracks are also present in the "Navigation area" tab but organized differently.

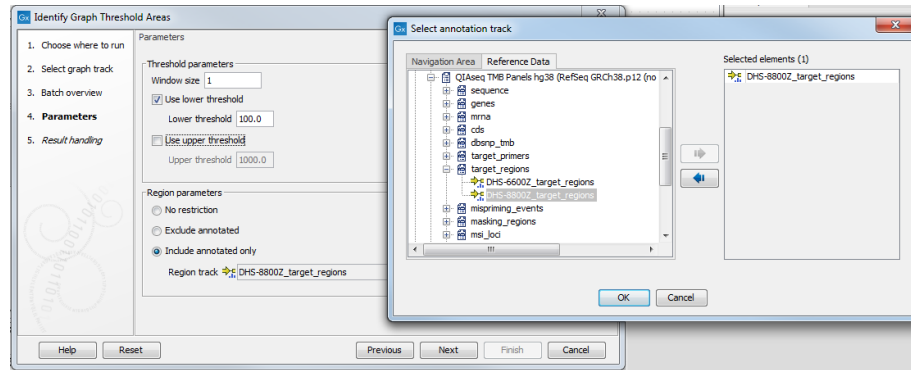





Figure 4: Set up the tool to generate target region tracks of minimum coverage 100X.

You can now start the Calculate TMB Score tool from the Toolbox:

Tools | QIaseq Panel Expert Tools  | QIaseq DNA Panel Expert Tools  | Calculate TMB Score 

Because each sample has now its own target region file, we cannot work in batch mode anymore, but you will need to repeat the following steps for each sample:

1. Select a variant track as seen in figure 5.

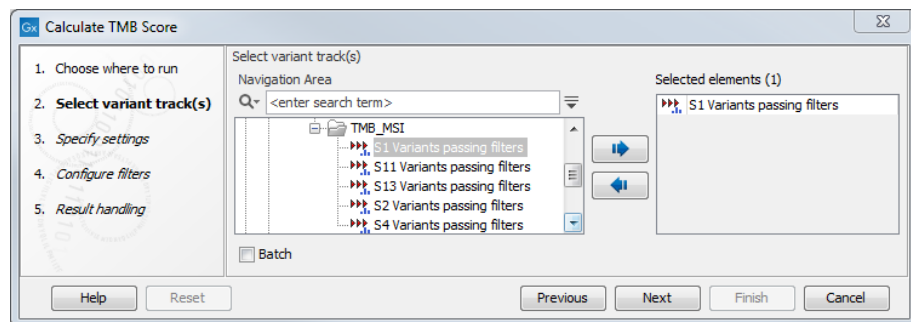


Figure 5: Select a variant track to generate the TMB Score report.

2. Now select from the Navigation Area the adjusted Target regions track you just generated for the sample (see figure 6). Then specify the Masking regions track specific to the DHS-8800Z panel. This file is included in the CLC_References folder of the Navigation Area once you have download the Reference Data Set. You will find it in the QIaseq TMB Panels hg38 (RefSeq GRCh.38.p12 (no alternative analysis set)) folder, in the subfolder named **masking_regions**. Again, select the "Reference Data" tab (highlighted in red) to be able to locate easily the reference tracks that belong to a given Reference Data Set.

Also, check the option "Enable TMB status detection using thresholds". We will leave the default thresholds, as these were chosen based on internal benchmark analyses of lung cancer cell lines and different tissue cancer samples. Given the lack of standardization of methods and the heterogeneity of tumor mutation burden across many tumor types, it is difficult to establish cutoff values. Thresholds should be set according to the samples analysed.

3. In the Configure filters dialog, leave all filters as they are set by default as these have been

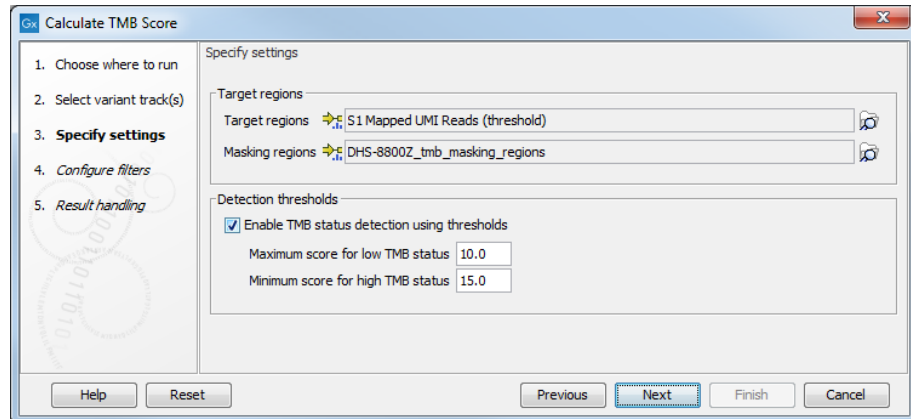


Figure 6: Select the target and masking regions tracks. We also choose to enable the TMB status in this tutorial.

configured to optimize sensitivity and specificity in selecting variants included in the TMB score calculation. Select from the Reference Data tab the Variant Database **db SNP_tmb** from the QIaseq TMB Panels hg38 (RefSeq GRCh.38.p12 (no alternative analysis set)) folder (figure 7)).

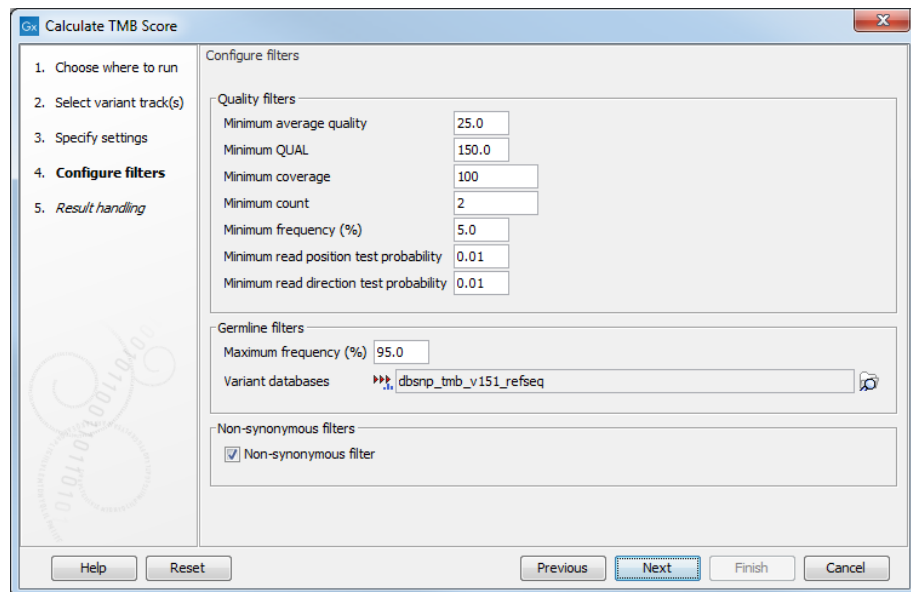



Figure 7: Select the db SNP variant database to filter out germline variants.

4. In the last dialog, choose the location where you want your reports to be saved and click **Run**.

Redo these steps for each sample, changing the variant track and the corresponding target regions file at each iteration.

The tool will output two files for each sample: the **Variants passing filters (TMB Somatic)** track, containing the variants that were used to calculate the TMB score. Indeed, the tool applies successively another round of various quality, germline and non-synonymous filters before calculating the score.

The **TMB** report () includes filtering statistics and the calculated TMB score and status. The TMB status is considered low if the TMB score is lower than 10; intermediate if the TMB score is between 10 and 15; and high if the TMB score is larger than 15. Note that these generic category cut-offs are only indicative and should not be used as cancer-specific classifications without proper validation by the user.

In addition to the TMB status, the report lists the length of the combined target regions, counts of various types of variants, and a value assigned to the tumor mutational burden calculated as the number of mutations per Mb. The quality filters statistics recapitulates how many variants were removed by the various filters applied by the tool. Finally, the report shows the frequency distributions of input and somatic variants.

Run the Analyze QIAseq Panel Guide

We will now run the TMB and MSI Panel (DHS-8800Z) workflow on all 5 samples with the Analyze QIAseq Panel guide.

1. Open the guide here:

QIAseq Panel Analysis | Analyze QIAseq Panel

and choose the TMB/MSI tab.

2. Click on the arrow to the right of the TMB and MSI Panel (DHS-8800Z) workflow, select the option **Somatic, Illumina (MSI)** as seen on figure 8 and click **Run**.

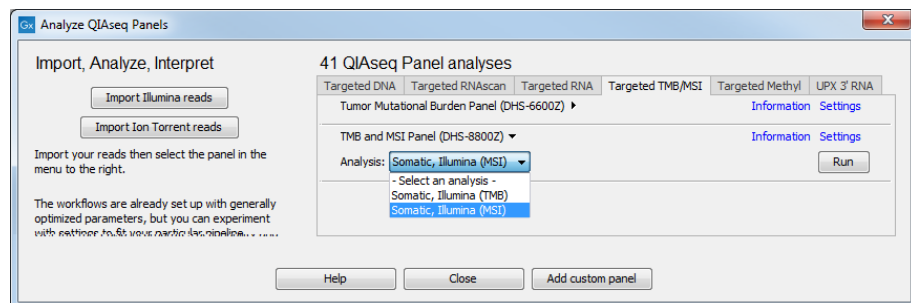


Figure 8: Select the 8800Z panel and choose the MSI workflow.

3. Check the batch mode (as highlighted in figure 9) before selecting the read mappings called **Mapped UMI Reads** that should be analyzed before clicking **Next**.
4. Finally, in the last wizard step, choose to **Save** the results of the workflow and specify a location in the Navigation Area before clicking **Finish**.

The workflow will output 5 MSI reports. You can now open side by side for each sample the TMB and the MSI reports (as we did for S2 in figure 10). S2 is MSI low, and its TMB score is also low.

By opening the other samples in a similar way, you will notice that TMB and MSI are not always correlated: Samples 11 and 13 are both MSI-high, but one has a low TMB score (S13), while the other has a high TMB score (S11). The same situation is happening for the MSS samples S1 (low TMB score) and S4 (high TMB score). While the consequences of TMB score and MSI status on potential therapies are still under investigation, QIAGEN panels and bioinformatics solution for standardized and consistent assessment of both.

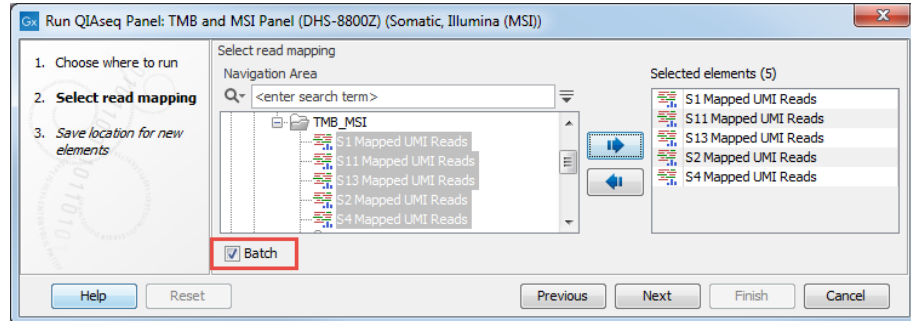


Figure 9: Select the sequencing reads. Remember to run them in batch mode!

S2 Variants passing filters U... X

1 Summary

TMB status	Low
Length of target regions (bp)	1,313,631
Variants inside target regions and after quality filters	51
Germline variants	50
Somatic variants	1
Non-coding somatic variants	0
Synonymous somatic variants	0
Non-synonymous somatic variants	1
Tumor mutational burden (mutations/Mb)	0.76
Tumor mutational burden confidence	High(*)

S2 Mapped UMI Reads (MSI report) X

1 Summary

The MSI status was detected using Coverage ratio and Standard deviation methods.
The MSI status of the sample can only be determined with at least 5 testable loci.

Sample name	S2 Mapped UMI Reads
Number of loci	9
Number of unstable loci	2
Number of stable loci	5
Number of not testable loci	2
Percentage of unstable loci	28.57
MSI status	MSI-L
Clinical term	MSI-Low

Locus	Coverage	Read Count	Sample Length	Baseline Length	Coverage ratio	Stability Threshold	Status
BAT40(T)37	972	0	37	[37]	-	-	N/A
MONO-27(T)27	2006	51	27	[27, 28, 29]	0.80	-	N/A
BAT26(A)27	2844	254	27	[14, 24, 25, 26, 27]	0.85	0.68	Stable
NR24(T)23	3116	215	23	[22, 23]	0.54	0.56	Unstable
BAT25(T)25	8806	886	46	[46, 47, 48]	0.37	0.55	Unstable
NR22(T)21	6494	1600	21	[21, 22, 23]	0.55	0.44	Stable
HSP110-T17(T)17	8942	3273	17	[16, 17, 18, 19]	0.82	0.68	Stable
NR21(A)21	7356	644	21	[18, 21, 22, 23, 24, 25, 27, 28]	0.89	0.46	Stable
BAT34C4(A)18	3404	909	39	[38, 39]	0.60	0.51	Stable

Figure 10: TMB and MSI reports opened simultaneously.

Bibliography

[A. Stenzinger et al., 2019] A. Stenzinger, J. A., Maas, J., Stewart, M., Merino, D., Wempe, M., and Dietel, M. (2019). Tumor mutational burden standardization initiatives: recommendations for consistent tumor mutational burden assessment in clinical samples to guide immunotherapy treatment decisions. *Genes C*, pages 1–11.

[Chang et al., 2018] Chang, L., Chang, M., Chang, H., and Chang, F. (2018). Microsatellite instability: A predictive biomarker for cancer immunotherapy. *Applied I*, 26(2):e15–e21.